NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2001 BUDGET ESTIMATES

EARTH SCIENCE BUDGET STRUCTURE CHANGE

NASA has restructured the Earth Science Budget in FY 2001 to display the resources being allocated to Research and Technology requirements in a way that can be more readily understood by NASA's customers. As a result, the Research and Technology requirements have been allocated into three categories: Earth Science Program Science, Applications Commercialization and Education (ACE) and Technology Infusion. This restructured format aligns the Research and Technology requirements with the way that they are managed within the Agency.

Given the complexity of the restructure, NASA has elected to cast the entire Earth Science Budget Narrative in the New Structure. A crosswalk from the Old Structure to the New Structure by Fiscal Year is provided in the Special Issues Section.

The following table summarizes the a Old Structure for FY 1999/FY 2000 and New Structure for FY 2001:

SCIENCE, AERONAUTICS, AND TECHNOLOGY	FY 1999 OLD STRUCTURE	FY 2000 OLD STRUCTURE	FY 2001 NEW STRUCTURE
OFFICE OF EARTH SCIENCE	**1413.8**	**1443.4**	**1405.8**
Major Development (New Structure)			
EOS	**632.4**	**575.4**	**447.1**
Terra	31.8	6.2	3.1
Aqua	113.1	92.8	42.9
Chem	132.8	124.7	110.3
Special	116.0	120.4	86.7
QuikScat	11.4	1.1	
Landsat-7	17.0	9.6	1.4
Algorithm Development	116.8	121.7	82.1
EOS Follow-on	4.5	24.4	120.6
Technology Infusion	89.0	74.5	
NMP	56.1	37.1	
Advanced Info Systems Tech	6.5	12.5	
Sensor and Detector (now titled Adv Tech Initiative)	5.5	9.9	
Instrument Incubator	20.9	15.0	
EOSDIS	**261.7**	**261.9**	**252.0**
Earth Probes	**109.3**	**157.4**	**120.4**
TOMS	9.9	24.8	0.5
UnESS		2.0	11.5
ESSP	62.3	94.5	105.9
LightSAR		0.0	
Triana	35.0	35.1	2.0
Experiments of Opportunity	2.1	1.0	0.5
Research and Technology (New Structure)			
Applied Research and Data Analysis	**399.7**	**436.5**	**533.3**
Science/Earth Science Program Science	323.6	359.4	353.2
Airborne	18.1	22.1	22.7
UAV Science	1.9	4.0	5.0
Commercial Remote Sensing	38.1	30.4	

SCIENCE, AERONAUTICS, AND TECHNOLOGY		FY 1999 OLD STRUCTURE	FY 2000 OLD STRUCTURE	FY 2001 NEW STRUCTURE
Mission Science Teams		48.1	55.8	100.0
R&A (included education and outreach)				
	EOS Science	46.4	60.3	52.2
	R&A	161.6	174.6	
	R&A - Research			163.6
	Education	9.4	12.2	
	Infor Systems			9.7
Applications Commercialization and Education				69.2
	R&A - Applications			21.2
	Commercial Remote Sensing			31.9
	Education and Outreach			16.1
	Education and Outreach			4.1
	EOS Fellowships			7.0
	GLOBE			5.0
Technology Infusion				110.9
	NMP			50.1
	Adv Infor Systems Tech			14.0
	Adv Technology Initiatives			10.0
	Instrument Incubator			15.0
	HPCC			21.8
Operations (New Structure)				**42.7**
Investments (New Structure)				**10.3**
Operations, Data Retrieval, and Storage		76.1	77.1	
	Mission Operations	55.5	47.6	
	HPCC	14.5	21.9	
	Info Systems	6.1	7.6	
GLOBE		**5.0**	**5.0**	
Launch Services		**4.2**		
SRTM			**6.2**	**0.0**
CofF		**1.5**	**1.0**	**0.0**

SCIENCE, AERONAUTICS, AND TECHNOLOGY

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF EARTH SCIENCE

OLD STRUCTURE

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Earth Observing System	632,400	575,415
Earth Observing System Data Information System	261,700	261,906
Earth Probes	109,300	157,400
Applied Research and Data Analysis	399,700	436,504
Earth Science Program Science	323,600	359,404
Operations, Data Retrieval and Storage	76,100	77,100
Global Observations to Benefit the Environment	5,000	5,000
Launch Services	4,200	--
Construction of Facilities	1,500	1,000
Shuttle Radar Topography Mission	--	6,200
Total	1,413,800	1,443,425

SCIENCE, AERONAUTICS, AND TECHNOLOGY

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF EARTH SCIENCE **EARTH SCIENCE**

PROPOSED NEW STRUCTURE

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	PAGE NUMBER
		(Thousands of Dollars)		
Major Development	[918,600]	[926,406]	819,500	
Earth Observing System	[547,600]	[500,900]	447,100	SAT 3-14
Earth Observing System Data Information System	[261,700]	[261,906]	252,000	SAT 3-29
Earth Probes (Includes SRTM)	[109,300]	[163,600]	120,400	SAT 3-36
Research and Technology	[439,700]	[469,419]	533,300	SAT 3-43
Earth Science Program Science	[251,800]	[286,300]	353,200	SAT 3-45
*Applications, Commercialization and Education	[82,900]	[85,704]	69,200	SAT 3-66
Technology Infusion	[103,500]	[96,415]	110,900	SAT 3-77
Construction of Facilities	[1,500]	[1,000]	--	SAT 3-84
Mission Operations	[55,500]	[47,600]	42,700	SAT 3-85
Investments (included in ACE in FY99-00)			10,300	SAT 3-90
Minority University Research & Education Program			8,800	
Education			1,500	
Total with Investment	[1,413,800]	[1,443,425]	1,405,800	

Distribution of Program Amount by Installation	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
Johnson Space Center	5,520	5,005	4,595
Kennedy Space Center	65,584	73,044	88,005
Marshall Space Flight Center	30,141	35,550	37,593
Stennis Space Center	39,491	32,845	36,290
Ames Research Center	15,868	17,394	15,239
Dryden Flight Research Center	16,432	20,500	20,450
Langley Research Center	74,073	87,047	101,667
Goddard Space Flight Center	882,418	895,380	811,984
Jet Propulsion Laboratory	247,300	248,174	248,492
Headquarters	36,973	28,486	41,485
Total	1,413,800	1,443,425	1,405,800

* Earth Science Program Science in FY01 has been broken out to reflect the distinction between the Research Program and the Applications, Commercialization and Education (ACE) Program. GLOBE after FY00 has been included under the ACE program. Detail of this content is provided in the narrative below.

EARTH SCIENCE ENTERPRISE

PROGRAM GOALS

The purpose of NASA's Earth Science Enterprise (ESE) is to observe the global Earth environment, to understand the mechanisms that underlie natural and human-induced environmental changes, and to identify consequences that could impact human societies. In short, the purpose of the Enterprise is to provide scientific answers to the fundamental question:

How is the Earth changing, and what are the consequences for human civilization?

A fundamental discovery made during the 20th century is the existence of a multiplicity of linkages between diverse natural phenomena and interactions between the individual components of the Earth system. As a result, a new "Earth system science" concept developed, with the aim of investigating the complex behavior of the total Earth environment in which the global atmosphere, the oceans, the solid Earth and ice-covered regions of the Earth, and the biosphere all function as a single interactive system. Earth system science is an area of research with immense benefits to the nation, yielding new knowledge and tools for weather forecasting, agriculture, water resource management, urban and land use planning, and other areas of economic and environmental importance. In concert with other agencies and the global research community, ESE is providing the scientific foundation needed for the complex policy choices that lie ahead on the road to sustainable development. ESE has established three broad goals. They are to 1) expand scientific knowledge of the Earth system using NASA's unique capabilities from the vantage points of space, aircraft and *in situ* platforms; 2) disseminate information about the Earth system; and 3) enable productive use of Earth science program science and technology in the public and private sectors.

NASA has long been pursuing a vision of an interdisciplinary Earth system science. Traditional scientific disciplines have already progressed a long way in the study of the atmosphere, biosphere, land, and oceans as quasi-independent components of a stationary Earth system, while treating the interfaces between components as prescribed boundary conditions. Building on these scientific achievements, the strategy of Earth system science is to promote a "coordinated [research] effort between adjacent scientific disciplines and observation programs focused on common interrelated problems that affect the Earth as a whole" (*Toward an International Biosphere-Geosphere Program*; National Research Council (NRC), 1983). The ultimate goal of the NASA Earth Science Enterprise is to achieve this synthesis and understand the interactive physical, chemical and biological processes that govern the total Earth system. With this knowledge, NASA and its partners will develop prediction capabilities to quantify the effects of natural and human-induced changes on the global environment. Operational agencies such as National Oceanic and Atmospheric Administration (NOAA) and United States Geological Survey (USGS), who are partners in this effort, can use these capabilities to improve weather and climate forecasting, natural resource management, and other services on which the Nation relies.

STRATEGY FOR ACHIEVING GOALS

The first Earth Science Research Plan, published in 1996, laid out a strategy for study in five Earth system science areas of maturing scientific understanding and significant societal importance: land-cover and land use changes; short-term climate events, natural hazards research and applications; long-term climate change research; and atmospheric ozone research. The plan also outlined some twenty related areas of research, which round out the Earth science contribution to Earth system science. NRC recognized the complexity of global Earth environment issues, the multiplicity of interactions between component processes and the cross-disciplinary connections they evoke (*Research Pathways for the Next Decade-Overview*; NRC, 1998). In the face of such complexity, the NRC outlined a diversity of unsolved scientific questions that call for further study, but also emphasized the need for a focused scientific strategy, concentrating efforts and resources on critical scientific problems that are most relevant to national policy issues. Responding to the latter recommendation, the ESE is developing a targeted research program, focused on an updated set of specific science questions that can be addressed effectively with NASA's capabilities, and formulating comprehensive research strategies that can lead to definitive scientific answers, as well as effective applications of those scientific results.

The key research topics studied by NASA's Earth Science Enterprise fall largely into three categories: forcings, responses, and the processes that link the two and provide feedback mechanisms. This conceptual approach applies in essence to all research areas of NASA's Earth science program, although it is particularly relevant to the problem of climate change, a major Earth science-related issues facing the countries of the world. The Earth Science Enterprise has articulated a set of science questions which its observational programs and research, modeling, and analysis activities are directed at answering**.**

- *How does the Earth change naturally?*
- *What are the primary forcings of the Earth system by human activities?*
- *How does the Earth system respond to natural and human-induced changes?*
- *What are the consequences of changes in the earth system for human civilization?*
- *How can we predict the changes in the Earth system that will take place in the future?*

NASA expects that expanded scientific knowledge of Earth processes and the utilization of advanced space-based and airborne observing techniques or facilities developed by NASA will result in practical applications beneficial to all citizens. Examples of these applications may include the prediction of impacts of environmental changes on fisheries, agriculture, and water resources; quantitative weather and hydrologic forecasts over an extended range of one to two weeks; prediction of seasonal or longer-range climate variations, global air quality forecasts, and natural hazards risk assessments. NASA ESE has a role in demonstrating the potential applications.

The pursuit of Earth system science would be impractical without the continuous, global observations provided by satellite-borne instruments. NASA's Earth science research program comprises an integrated slate of spacecraft and *in situ* measurement capabilities; data and information management systems to acquire, process, archive and distribute global data sets; and research and analysis projects to convert data into new knowledge of the Earth system. Numerous users in academia, industry, Federal, State, and local government use this knowledge to produce products and services essential to achieving sustainable development. Enabling us to get at the answers to the science questions, our top priority continues to be our existing near term commitments with the launch of our first series of EOS and selected Earth probe missions that are nearing completion. In addition, we are committed to deliver a functioning data and information system to support the processing, archival and distribution of data products for these missions. These satellites will propel the Enterprise into a new era of data collection, research and analysis for which both the national and international Earth science community has been preparing over the last decade.

The Earth Observing System (EOS), the centerpiece of Earth science, is a program of multiple spacecraft (the Terra, Aqua (formerly PM), Chemistry, Landsat-7 Jason-1, ICEsat, ACRIMSAT and follow-on missions) and interdisciplinary science investigations to provide a data set of key parameters needed to understand global climate change. The first EOS satellite launches began in 1999. Preceding the EOS were a number of individual satellite and Shuttle-based missions that are helping to reveal basic processes. The Upper Atmosphere Research Satellite (UARS), launched in 1991, collects data on atmospheric chemistry. The Total Ozone Mapping Spectrometer (TOMS) instruments, launched in 1978, 1991, and 1996, measure ozone distribution and depletion. Two TOMS instruments were launched in 1996, one on the Japanese Advanced Earth Observing System (ADEOS) mission and the other on a dedicated U. S. Earth Probe. France and the U. S. collaborated on the Ocean Topography Experiment (TOPEX/Poseidon), launched in 1992, to study ocean topography and circulation. QuikScat**,** which was launched after a one-year development**,** is providing measurements originally provided by the NASA Scatterometer (NSCAT)**,** which mapped ocean winds for one year prior to an on-orbit failure of the Japanese ADEOS-I. In 1997, the Tropical Rainfall Measuring Mission (TRMM) was launched to provide the first-ever measurements of tropical precipitation. Also in 1997, ESE began purchasing ocean color data from a commercial vendor based on our joint investment in the SeaWifs instrument.

Complementing EOS, under the Earth Probes Program, will be a series of small, rapid development Earth System Science Pathfinder (ESSP) missions to study emerging science questions and to use innovative measurement techniques in support of EOS. The first two ESSP missions, Vegetation Canopy LIDAR (VCL) and Gravity Recovery and Climate Experiment (GRACE) are scheduled for launch in 2000 and 2001, respectively. The next ESSP missions were selected in December 1998. The first is the Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations – *Climatologie Etendue des Nuages et des Aerosols* (PICASSO-CENA) mission. The second is the CloudSat mission. Both are scheduled for launch in 2003. The scientific objectives of the TOMS project are to measure the long-term changes in total ozone and to verify the chemical models of the stratosphere used to predict future trends. The TOMS Flight Model-5 has been completed, and was scheduled to fly as a cooperative mission with Russia in late 2000. However, Russia has indicated that it cannot meet that launch date. Presently, the Agency has completed its re-planning and will be ready to fly FM-5, as QuikToms, on a US vehicle and spacecraft in August 2000.

In developing its measurement/mission strategy, the Earth Science Enterprise desires to reduce the risk to overall program objectives from any single mission failure by developing smaller, less expensive missions and implementing shorter development cycles from mission definition to launch. Shorter development times will allow more flexible responses to current and evolving scientific priorities and more effective uses of the latest technologies. In accordance with this philosophy, the implementation of each successive future mission in the ESE flight program will be based on specific solicitation alternatives (e.g. Announcement of Opportunity, Request for Proposal, etc.) and competitive selection of instrument payloads and implementation options. In each solicitation, we will ask commercial industry to come forward and offer science-quality data that meet NASA requirements. It is important, under this new approach, that instrument technology developments be conducted largely before the relevant mission payload selection. A science and applications-based space-based measurement concept set is indispensable to guide these pre-mission technology developments, particularly the Enterprise's Instrument Incubator Program. Our goal is to reach a mission development cycle of two-three years from the time of selection.

NASA ESE is developing a science implementation plan, which will drive the selection of Earth observation satellite missions in the 2003-2010 time frame. An early, high priority in this timeframe is the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Preparatory Program (NPP), which will serve to provide continuity with the Terra and Aqua missions as well as a demonstration of instruments for the converged weather satellite program. NASA and the Integrated Program Office

(IPO) jointly fund the NPP mission. The IPO consists of representative from the three agencies participating in NPOESS – NASA, the National Oceanic and Atmospheric Administration, and the Air Force.

Data from Earth science missions, both current and future, will be captured, processed into useful information, and broadly distributed by the EOS Data Information System (EOSDIS). EOSDIS will ensure that data from these diverse missions remain available in active archives for use by current and future scientists. Since these data are expected to find uses well beyond the Earth science research community, EOSDIS will ultimately be accessible by environmental decision-makers, resource managers, commercial firms, social scientists and the general academic community, educators, state and local government—anyone who wants the information.

Following the recommendation of the National Research Council, NASA is exploring the creation of a federation of Earth science information partners in academia, industry and government to broaden the participation in the creation and distribution of EOSDIS information products. As a federation pilot project, 24 organizations were competitively selected in December 1997 to become Earth Science Information Partners (ESIPs) to develop innovative science and applications products. This is part of a broader analysis of how ESE's approach to data and information systems services should evolve in the future.

The intellectual capital behind Earth science missions, and the key to generating new knowledge from them, is vested in an active program of research and analysis. Over 1,500 scientific research tasks from nearly every state within the U. S. are funded by the Earth science research and analysis program. Scientists from seventeen other nations, funded by their own countries and collaborating with U. S. researchers, are also part of the Earth science program. These researchers develop Earth system models from Earth science data, conduct laboratory and field experiments, run aircraft campaigns, develop new instruments, and thus expand the frontier of our understanding of our planet. ESE-funded scientists are recognized as world leaders in their fields, as exemplified by the award of the 1995 Nobel Prize in chemistry to two scientists who first recognized that cholorflorocarbons provided a threat to upper atmospheric ozone. The research and analysis program is also the basis for generation of application pilot programs that enable universities, commercial firms, and state and local governments to turn scientific understanding into economically valuable products and services.

From FY 2000 on, there is increased emphasis on a viable Applications, Commercial and Education (ACE) program that bridges our focused Research and Analysis (R&A) and mission science investments with the Applications and Commercial Remote Sensing Program towards demonstration of new remote sensing data products for industry and regional and local decision makers. The need is to focus on the dissemination of information to non-traditional Earth science customers, such as States, counties and regional managers and decision-makers. This budget identifies initial funding requirements for the Digital Earth Initiative designed to develop usable, remote sensing-based information products for state and local users around the Nation and beyond. A base program is funded to put the essential tools in place and pilot several key demonstration projects. Eventually we hope that our demonstration of this concept will allow products to reach a much broader user base – practically every state in the Union.

The challenges of Earth System Science, sustainable development, and mitigation of risks to people, property and the environment from natural disasters, require collaborative efforts among a broad range of national and international partners. NASA's Earth science research program constitutes its contribution to the U.S Global Change Research Program (USGCRP), an interagency effort to understand the processes and patterns of global change. The USGCRP coordinates research among ten U. S. government agencies. NASA is by far the largest partner in the USGCRP, providing the bulk of USGCRP's space-based observational needs. NASA has extensive collaboration with the NOAA on climate-related issues. The ESE is the responsible managing agent in NASA for the

development of NOAA's operational environmental satellites. NOAA, NASA, and the Department of Defense (DoD) jointly work to achieve the convergence of civilian and military weather satellite systems. NASA collaborates with the USGS on a range of land surface, solid Earth and hydrology research projects. NASA and USGS collaborate in the Landsat-7 program, and NASA, DoD and USGS are working together on a third flight of the Shuttle Radar Laboratory modified to yield a digital terrain map of most of the Earth's surface. NASA participates in the World Climate Research Program, the International Geosphere/Biosphere Program, and the ozone assessments of the World Meteorological Organization.

International cooperation is an essential element in the Earth science program. Earth science addresses global issues and requires international involvement in its implementation and application. Acquiring and analyzing the information necessary to address the science questions is a bigger task than a single nation can undertake. Furthermore, the acceptance and use of the scientific knowledge in policy and resource management decisions around the world require the engagement of the international scientific community. Global data and global participation are needed to devise a global response to environmental change. In addition, integrating our complementary science programs can result in fiscal benefits to the NASA program. For this reason, NASA has sought and nurtured international partnerships spanning science, data and information systems, and flight missions. Most of Earth science's satellite missions have international participation, ranging from simple data sharing agreements to joint missions involving provision of instruments, spacecraft, and launch services. In the past three years over 60 international agreements have been concluded and more than 40 more are pending. In some capacity, Earth science programs involve international partners from over 35 nations, including Argentina, Armenia, Australia, Belgium, Brazil, Canada, Chile, China, Denmark, Egypt, France, Germany, India, Israel, Italy, Japan, Mongolia, Russia, South Africa, Ukraine and others.

In addition to ensuring a robust science program, this budget contains a vigorous Advanced Technology program that supports development of key technologies to enable our future science missions. In addition to our baseline technology program that includes the New Millennium Program (NMP), Instrument Incubator and High Performance Computing and Communications (HPCC), an Advanced Technology Initiative will identify and invest in critical instrument, spacecraft and information system technologies.

The ESE will lead the way in the development of highly capable, remote and *in situ* instruments and the information system technologies needed to support coupled Earth system models. Together they will enable affordable investigation and broad understanding of the global Earth system. The ESE will emphasize the development of information system architectures to increase the number of users of Enterprise information from hundreds to tens of thousands, with the goal of providing easy access to global information for science, education and applications. Finally, ESE will work in partnership with industry and operational organizations to develop the capabilities and infrastructure to facilitate the transition of sustained measurements and information dissemination to commercial enterprises.

ESE's technology strategy seeks to leverage the entire range of technology development programs offering benefits in cost, performance and timeliness of future Earth science process and monitoring campaigns. ESE's strategy is to establish strong links to other government programs in order to maximize mutual benefit to use open competitions for ESE-sponsored technology programs to attract the best ideas and capabilities from the broad technology community, including industry and academia.

Technology efforts will be made in the following areas:

- Advanced instrument and measurement technologies for new and/or lower cost scientific investigations;

- Cutting-edge technologies, processes, techniques and engineering capabilities that reduce development, operations costs, and mission risk and that support rapid implementation of productive, economical, and timely missions;
- Advanced end-to-end mission information system technologies: technologies affecting the data flow from origination at the instrument detector through data archiving, for collecting and disseminating information about the Earth system, and enabling the productive use of Enterprise science and technology in the public and private sectors.

Terra (formerly AM) was recently launched on December 18, 1999. Terra will provide key measurements that will significantly contribute to our understanding of the total Earth system. The instrument complement will obtain information about the physical and radiative properties of clouds, air-land and air-sea exchanges of energy, carbon, and water, measurements of trace gases, and volcanology.

Landsat-7 was also launched in 1999. Landsat-7's single instrument, the Enhanced Thematic Mapper Plus (ETM+), is making high spatial resolution measurements of land surface and surrounding coastal regions. This mission is successfully providing data continuity with previous Landsat measurements. Landsat data is used for global change research, regional environmental change studies, and other civil and commercial purposes.

With the EOS missions, such as QuikScat, Terra, Landsat-7, and ACRIMSAT that were launched in 1999, NASA is beginning to turn flight data into information. In addition to the EOSDIS that will produce data products for a wide range of users, NASA is engaging in a variety of activities to extend the utility of Earth Science data to a broader range of users such as regional Earth science applications centers, Earth science information partners, and efforts are under way to fuse science data, socio-economic data and other data sets that can be "geo-referenced" in readily understandable data visualizations.

The first of two cooperative missions with the Russian Space Agency (RSA), the Meteor-3M (1) Stratospheric Gas and Aerosol Experiment (SAGE III) mission, had been planned for launch in 1999. At this time it is uncertain that the Russians will meet their commitment to be ready to launch SAGE III in FY 2000. The instrument is completed and in storage at LaRC in the meantime but will not be shipped due to safety related issues until the spacecraft is ready to accommodate its integration. This mission will collect global profiles of key gaseous species from the troposphere to the mesosphere. The science team will investigate spatial and temporal variability and investigate the effects of aerosols and clouds on the Earth's environment. The Russian METEOR-3M (2) spacecraft had planned to carry the last planned TOMS into orbit in 2000, providing continuity in the essential measurement of the total column of ozone in the stratosphere. This past year, NASA learned that Russia would not be able to meet its goals for producing a spacecraft and launch vehicle for the TOMS instrument. Since then, NASA and the RSA mutually agreed to terminate cooperative activities on the project and we are currently implementing QuikToms using an U.S. provided launch vehicle and spacecraft.

The QuikScat spacecraft was launched in April 1999. QuikScat, carrying instruments to collect sea surface wind data, is filling the gap in such critical data between ADEOS 1, which failed in June 1997 after seven months on-orbit, and ADEOS II. The availability of components of the Seawinds instrument originally planned for launch on Japan's ADEOS II was accelerated to fly on QuikScat. Japan has yet to decide on the timing and form of an ADEOS II mission (or missions), but the ESE still intends to fly a Seawinds instrument in that context as the follow-on instrument to QuikScat. It now appears that ADEOS-II will be launched no earlier than late 2001 with the delay due in part to a failure of a Japanese launch vehicle.

The Active Cavity Radiometer Irradiance Monitor Satellite (ACRIMSat) was launched on December 20, 1999 providing for the continuation of the long-term, quantitative understanding of the solar forcing of Earth's climate.

The measurements to be made by these and other future Earth science missions as well as current on-orbit missions provide data products that are used extensively in the Earth science program. These activities are providing an ever increasing scientific understanding of global environment and the effects of natural and human sources of change.

BASIS OF FY 2001 FUNDING REQUIREMENT

OLD STRUCTURE
EARTH OBSERVING SYSTEM

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Terra	31,800	6,200
Aqua (formerly PM-1)	113,100	92,800
Chemistry	132,800	124,700
Special Spacecraft	116,000	120,400
QuikScat	11,400	1,100
Landsat-7	17,000	9,600
Algorithm Development	116,800	121,700
EOS Follow-on	4,500	24,400
Technology Infusion	89,000	74,515
Total	632,400	575,415

BASIS OF FY 2001 FUNDING REQUIREMENT

MAJOR DEVELOPMENT

PROPOSED NEW STRUCTURE
EARTH OBSERVING SYSTEM

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Terra	[31,800]	[6,200]	3,100
Launch Services	[4,200]	--	--
Aqua (formerly PM-1)	[113,100]	[92,800]	42,900
Chemistry	[132,800]	[124,700]	110,300
Special Spacecraft	[116,000]	[120,400]	86,700
QuikScat	[11,400]	[1,100]	--
Landsat-7	[17,000]	[9,600]	1,400
Algorithm Development	[116,800]	[121,700]	82,100
EOS Follow-on	[4,500]	[24,400]	120,600
Total	[547,600]	[500,900]	447,100

Note: in the new proposed structure, Technology Infusion is located under Research and Technology.

PROGRAM GOALS

The overall goal of the Earth Observing System (EOS) is to advance the understanding of the entire Earth system on a global scale by improving our knowledge of the components of the system, the interactions between them, and how the Earth system is changing. The EOS data will be used to study the atmosphere, oceans, cryosphere, biosphere, land surface and solid Earth, particularly as their interrelationships are manifested in the flow of energy and in the cycling of water and other chemicals through the Earth system.

The EOS program mission goals are to:

(1) Create an integrated, scientific observing system emphasizing climate change that will enable multi-disciplinary study of the Earth's critical, life-enabling, interrelated processes.
(2) Develop a comprehensive data information system, including data retrieval and processing system.
(3) Serve the needs of scientists performing an integrated multi-disciplinary study of planet Earth and to make Earth science data and information publicly available.
(4) Acquire and assemble a global database for remote sensing measurements from space over a decade or more to enable definitive and conclusive studies of Earth system attributes.

STRATEGY FOR ACHIEVING GOALS

The EOS contributes directly to accomplishing the goal of understanding global climate by providing a combination of observations made by scientific instruments, which will fly aboard the EOS spacecraft, and the data received, archived, processed, and distributed by the EOSDIS. The selection of scientific priorities and data products responds directly to the USGCRP global change science priorities and the assessment by the Intergovernmental Panel on Climate Change of the scientific uncertainty associated with global climate change.

The three main EOS spacecraft that will support observations by the scientific instruments include the morning (AM) renamed Terra, afternoon (PM) renamed Aqua, and Chemistry missions. Beginning in 1999, 2000, and 2002 respectively, the satellites will be flown for a period of six years. Additional observations are provided by the Landsat-7 mission, successfully launched on April 15, 1999.

Nearly all-key EOS missions include international contributions. For example, the Terra spacecraft is flying an instrument from Canada Measurements of Pollution of the Troposphere (MOPITT) and one from Japan (Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)); Aqua will include the Japanese Advanced Microwave Scanning Radiometer (AMSR) instrument and the Humidity Sounder for Brazil (HSB). Chemistry will include the Dutch-Finnish Ozone Monitoring Instrument (OMI) as well as the High-Resolution Dynamics Limb Sounder (HRDLS) instrument jointly produced by the U.S. and the United Kingdom. In addition, numerous agreements have been signed for joint data exchange and distribution, including cooperation in EOSDIS.

The 1997 Biennial Review completed the shift in planning for future missions (i.e., beyond the EOS first series). Emerging science questions drive measurement requirements, which drive technology investments in advance of instrument selection and mission

design. Mission design includes such options as purchase of science data from commercial systems and partnerships with other Federal agencies and international agencies. The result is a more flexible and less expensive approach to acquiring Earth science data.

The ESE recognizes that the pathways of global change research lead from specialized studies of fundamental processes to the integration of individual findings into interactive models of the global Earth system, which can eventually deliver reliable predictions of natural or human-induced environmental phenomena. Long, consistent time-series of global environmental measurements are needed to document changes in forcing parameters and corresponding variations in the state of the Earth system, as required to explore the range of natural variability and test mathematical models of the phenomena. While diagnostic studies based long time series of global measurements can reveal the nature of the underlying mechanisms, focused process studies are indispensable to identify and model the basic physical, chemical and biological processes involved. Understanding these component processes is crucial in order to achieve the goal of constructing reliable predictive models of the Earth system. For this reason, the ESE aims to achieve a proper balance between long-term systematic measurements of key forcing or response parameters, and specialized process research. NASA ESE is in the process of developing a science implementation plan, which will drive the selection of the follow-on missions.

Terra

A new generation of Earth science began with the launch and checkout on December 18, 1999 of Terra - one that studies the Earth as a global system. Because the Terra spacecraft primarily observes terrestrial features, a morning equatorial crossing time is preferred to minimize cloud cover over land. Terra carries a complement of five synergistic instruments. The Clouds and Earth's Radiant Energy System (CERES) instrument will perform measurements of the Earth's "radiation budget" or the process by which the Earth's climate system maintains a balance between the energy that reaches the Earth from the sun, and the energy that radiates from Earth back into space. The components of the Earth system that are important to the radiation budget are the planet's surface, atmosphere, and clouds. The Multi-angle Imaging Spectroradiometer (MISR) will measure the variation of the surface, aerosol, and cloud properties with the direction from which the Earth is viewed from space (Most other instruments only measure one such direction at a time, while MISR measures nine directions simultaneously). Meanwhile, the Moderate-Resolution Imaging Spectroradiometer (MODIS) will measure atmosphere, land, and ocean temperature, and moisture profiles, snow cover, and information about the state of the biosphere on both land surface and under the top layers of the ocean. The Canadian MOPITT instrument is an infrared gas-correlation radiometer that will take global measurements of carbon monoxide and methane in the troposphere. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument, provided by Japan, will measure cloud properties, vegetation index, surface mineralogy, soil properties, surface temperature and obtain digital elevation modes. The primary contractors associated with the project are Lockheed Martin Missiles and Space (LMMS) for the Terra spacecraft, Raytheon Sensors and Electronic Systems for the MODIS instrument, TRW for the CERES instrument (the instrument has also been flown on the TRMM in 1997), and Lockheed Martin Commercial Launch Services for the Terra Atlas Centaur/IIAS launch service.

Aqua (formerly PM-1)

The research focus of the Aqua spacecraft is atmospheric temperatures and humidity profiles, clouds, precipitation, and radiative balance; terrestrial snow and sea ice; sea-surface temperature and ocean productivity; soil moisture; and the improvement of numerical weather prediction. With the emphasis of the instrument complement being cloud formation, precipitation, and

radiative properties, an afternoon equatorial crossing is more suitable for acquiring the data. The primary contractors associated with the project are TRW for the common spacecraft to be used for Aqua; Lockheed Martin Infrared and Imaging Systems (LMIRIS) and JPL for the Advanced Infrared Sounder (AIRS) instrument; and Aerojet for the Advanced Microwave Sounding Unit-A (AMSU-A) instrument. Japan will provide the AMSR-E instrument for the Aqua spacecraft and Brazil will provide a microwave instrument, the HSB. The launch of Aqua is scheduled for December 2000. Boeing provides the launch vehicles and services for the EOS-Aqua mission.

Chemistry

The Chemistry mission focuses on the impact of greenhouse gases on the global climate. The Project is in Phase C/D developments. The Tropospheric Emission Spectrometer (TES), the Microwave Limb Sounder (MLS), and the High-Resolution Dynamics Limb Sounder (HIRDLS) have completed their Preliminary Design Reviews (PDR) in 1997 and 1998 and are now reaching a high level of design maturity. The Ozone Monitoring Instrument (OMI) will provide information on the distribution of ozone, aerosols, and several other trace atmospheric constituents. The Netherlands and Finland contribute it. The OMI has successfully completed its PDR in December 1998. The launch of Chemistry-1 is scheduled for December 2002.

Special Spacecraft

The Special spacecraft will be designed to study atmospheric aerosols, ocean circulation, ice-sheet mass balance, cloud physics, atmospheric radiation properties, and solar irradiance. Ball Aerospace and Technologies Corporation was responsible for developing the Stratospheric Gas and Aerosol Experiment (SAGE III) that is planned to fly on a Russian spacecraft in 2000, if the Russian launch vehicle and spacecraft are ready. A second SAGE III instrument is scheduled to fly aboard the International Space Station in 2003, and a third instrument has been built and is awaiting identification of an appropriate flight opportunity. The SAGE III will take advantage of both solar and lunar occultation to measure aerosol and gaseous constituents of the atmosphere. The Japanese will provide the Advanced Earth Observing System II (ADEOS II) spacecraft for the Seawinds instrument to measure ocean surface wind velocity as a follow-on to the NASA Scatterometer instrument on ADEOS-I and the Seawinds instrument on QuikScat. The Radar Altimetry mission, Jason-1, will be a follow-on to the TOPEX/Poseidon as a cooperative joint mission with the French Space Agency (CNES), with data provided to NOAA for operational purposes. The EOS Laser Altimetry mission was renamed Ice, Clouds and Land Elevation Satellite (ICESat) to denote its primary objectives of measuring ice sheet height and volume for long-term climate variability studies. The EOS ACRIMSAT will continue the measurement of Total Solar Irradiance (TSI) begun by the ACRIM instruments on the Solar Maximum Mission and UARS.

The Total Solar Irradiance Mission (TSIM) was merged with the Solar Stellar Irradiance Comparison Experiment (SOLSTICE) Mission to form the Solar Radiation and Climate Experiment (SORCE) Mission. SORCE will accomplish all the original science objectives of both TSIM and SOLSTICE including those requirements defined by the National Polar-orbiting Operational Environment Satellite (NPOESS). The SORCE spacecraft will be launched in July 2002.

The ESE is committed to provide a launch vehicle for the Canadian SciSAT mission. Reductions of funds in FY 2000 will be somewhat alleviated since the planned launch date for the SciSAT has slipped several months from December 2001. The launch vehicle payment schedule will be renegotiated in FY 2001 to fully meet our commitment.

Landsat-7

The Landsat-7 satellite was launched on April 15, 1999, and declared operational in July 1999. The satellite has been returning excellent images, which meet or exceed NASA's expectations. First data was available to public mid-August 1999. By agreement with the United States Geological Survey (USGS), NASA is operating and funding operations in FY 2000. Beginning in FY 2001, the USGS will operate the Landsat-7 system. The Landsat-7 Government/industry team received the American Institute for Aeronautics and Astronautics award.

EOS Follow-On

The next generation of EOS missions will provide new technology and space systems to meet the scientific needs for the NASA Earth science projects. NASA ESE is in the process of developing a science implementation plan, which will drive the selection of future missions. Preliminary mission studies have suggested possible technology needs as an input to technology project planning. New instrument technologies will be tested, validated, and made available to support science proposals for selection of measurements, principal investigators, and instruments for the next EOS missions. All EOS measurements, principal investigators, and instruments will be selected as a result of a broad agency announcement that will include peer review, with the goal of a first planned follow on launch for FY 2004. Launches are expected each year through 2009.

In September 1998, NASA, NOAA and DOD agreed jointly to investigate the feasibility of a joint venture to provide continuity of key climatic changes of global observations and provide risk reduction demonstration of key National Polar-orbiting Operational Environmental Satellite System (NPOESS) sensors, algorithms and processing prior to the first flight of the NPOESS. In April 1999, NASA, NOAA and DOD agreed to jointly formulate this vision under the management of NASA and the Integrated Program Office (IPO). The NPOESS Preparatory Project (NPP) mission is a continuation of key measurements from Terra and Aqua with the end of their operational life. The tentative launch date is 2005. The mission is in formulation studies anticipating a formal authority to proceed in the spring of 2001.

SCHEDULE AND OUTPUTS

Preliminary Design Reviews - Confirms that the proposed project baseline is comprehensive (meets all project level performance requirements), systematic (all subsystem/component allocations are optimally distributed across the system), efficient (all components relate to a parent requirement), and represent acceptable risk.

Seawinds
Plan: May 1995
Actual: May 1995

Meteor-3M Stratospheric Aerosol & Gas Experiment (SAGE III)
Plan: July 1995
Actual: July 1995

Aqua (formerly PM-1)
Plan: April 1997
Actual: April 1997

Jason
Plan: June 1997
Actual: June 1997

ACRIM
Plan: March 1998
Actual: March 1998

ICESat
Plan: June 1998
Actual: June 1998

Chemistry
Plan: March 1998
Actual: October 1999

Rescheduled following completion of alternative configuration studies.

SORCE
Plan: May 1999
Actual: May 1999

SOLSTICE and TSIM were combined in FY 1999 to make the SORCE mission. The Mission Design Review and the Preliminary Design Review were combined and successfully conducted in May 1999.

NPP
Plan: December 2002

Critical Design Reviews - Confirms that the project system, subsystem, and component designs, derived from the preliminary design, is of sufficient detail to allow for orderly hardware and software manufacturing, integration and testing, and represents acceptable risk. Successful completion of the critical design review freezes the design prior to actual development.

ACRIM:
Plan: January 1998
Actual: January 1998

Aqua (formerly PM-1)
Plan: April 1998
Revised: June 1998

Revised schedule due to late start following resolution of protest first reported in the 1998 budget

Jason:
Plan: November 1998
Actual: November 1998

SORCE
Plan: October 2000

Chemistry
Plan: August 2000

Rescheduled following completion of alternative configuration studies.

NPP
Plan: December 2003

Instruments Delivered - Confirms that the fabrication, integration, certification, and testing of all system hardware and software conforms to their requirements and is ready for recurring operation. Throughout system development, testing procedures or, as appropriate, engineering analysis have been employed at every level of system synthesis in order to assure that the fabricated system components will meet their requirements.

Landsat-7
Plan: December 1996
Actual: September 1998

Terra last instrument
Plan: February 1997
Actual: August 1997

Test anomalies occurred on the MOPITT instrument; which required rework by Canadians.

SAGE-III (Russian)
Plan: December 1997
Actual: September 1998

Due to instrument and detector testing problems.

Seawinds
Plan: March 1998
Revised: March 1999

Delayed due to launch slip by Japan.

Aqua (formerly PM-1) last instrument
Plan: September 1999
Actual: December 1999

Instrument deliveries delayed, first reported in the 1998 budget

ICESat
Plan: October 2000

Chemistry-1 last instrument
Plan: January 2002

Rescheduled following completion of alternative configuration studies.

QuikScat
Plan: May 1998
Actual: May 1998

ACRIM
Plan: October 1998
Actual: June 1999

Instrument delivery changed to fit new launch schedule after selection of launch vehicle and spacecraft vendors.

Jason-1 Revised due to CNES spacecraft need date.
Plan: March 1999
Actual: September 1999

SORCE: TSIM and SOLSTICE were combined in FY 1999 to create the SORCE mission.
Plan: August 2001

NPP
Plan: October 2004

Algorithm Development (Version 2) - Confirms that the second version of the science software necessary for the production of the standard data products for each mission has been developed and is ready to support launch.

Terra
Plan: February 1998
Actual: February 1998

Aerosol SAGE-III (Russian) Commensurate with the delay in instrument delivery.
Plan: June 1999
Actual: March 2000

Seawinds
Plan: September 1998
Actual: September 1998

Jason-1 Revised due to delayed selection of science team and revised launch date.
Plan: October 1999
Actual: December 1999

Aqua (formerly PM-1)
Plan: July 2000

Chemistry
Plan: December 2001

ICESat Revised due to delay selection of science team.
Plan: January 2001

Launch Readiness Dates - Verifies that the system elements constructed for use, and the existing support elements, such as launch site, space vehicle and booster, are ready for launch.

Terra Plan: July 1999 Actual: December 1999	Due to RL10-11 engine standdown, the Terra launch was delayed until the launch vehicles were returned to a flight readiness status. Terra was successfully launched on December 18, 1999.
QuikScat Plan: April 1999 Actual: June 1999	Delayed due to USAF Titan IV failure investigations and launch site availability conflicts.
Landsat-7 Plan: April 1999 Actual: April 1999	Landsat-7 was successfully launched on April 15, 1999.
ACRIMSAT Plan: November 1999 Revised: December 1999	ACRIMSAT was successfully launched on December 20, 1999.
Aerosol SAGE-III (Russian) Plan: September 1999 Revised: TBD	Instrument ready. Awaiting Russian readiness to accept payload.
Seawinds (ADEOS-II) Plan: November 2000 Revised: November 2001	Instrument delivered and integrated onto the spacecraft. Delay due to Japanese launch vehicle problem.
Jason 1 Plan: May 2000 Revised: TBD	All NASA instruments were delivered to CNES in 1999. Delayed to accommodate satellite and altimeter development by French Space Agency (CNES) partner.
Aqua (formerly PM-1) Plan: December 2000	
Chemistry Plan: December 2002	
ICESat Plan: January 2002 Revised: July 2001	Project schedule accelerated due to acquisition of spacecraft bus through the Rapid Spacecraft development procurement mechanism
SORCE: Plan: July 2002	TSIM and SOLSTICE were combined in FY 1999 to the SORCE mission.
NPP Plan: December 2005	

ACCOMPLISHMENTS AND PROPOSED RESULTS

Terra

In April 1999, the spacecraft was delivered to the Astrotech commercial launch processing facility at the Vandenberg AFB, California, where system end-to-end testing was performed and launch preparations were completed. The Delta Flight Operations Review was successfully completed. Terra was successfully launched on December 18, 1999.

Aqua (formerly PM)

During FY 1999, fabrication of the spacecraft structure was completed with subsystem integration onto the spacecraft initiated. All of the six instruments have been delivered for integration onto the spacecraft. Instrument integration onto the spacecraft will continue through January 2000. The Pre-Environmental Review is scheduled for February 2000 with the test program to follow. Shipment to the Western Test Range is planned for November 2000, which is consistent with the manifested launch readiness date of December 2000. Final science instrument algorithms are on plan and the ground system operations are proceeding in support of the December 2000 launch. Observatory and instrument checkout will occur for approximately 90 days after launch wherein nominal mission operations will commence.

Chemistry

The Chemistry mission focuses on the impact of greenhouse gases on the global climate. The Project is in Phase C/D development. The HIRDLS instrument completed CDR in April 1999, the TES completed its CDR in June 1999, and the MLS completed its CDR in September 1999. All of these instruments have reached a high level of design maturity. The Netherlands and Finland contribute the OMI instrument. The OMI CDR was held in October 1999.

The Spacecraft delta PDR was held in November 1999 to assess what changes would need to be incorporated into the common spacecraft bus to accommodate the Chemistry Mission. The successful delta PDR showed that many of the spacecraft subsystems have already reached a CDR level of maturity. The Launch of Chemistry is scheduled for December 2002.

Special Spacecraft

The Jason MOU between NASA and CNES was signed in December 1996. CNES will provide the spacecraft, solid-state altimeter, and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) positioning system. NASA will provide the microwave radiometer, global positioning system and laser retroreflector array. The ground system and mission operations will be shared. NASA will also provide the launch services. Delays in the CNES satellite development program and altimeter development have caused the launch of Jason to be rescheduled. A revised launch date has not yet been determined. NASA supported a Jason-1 PDR in June 1997 and initiated the Boeing Delta II launch vehicle contract in September 1997.

The Jason activities for 1998 focused on the completion of the critical design for all flight elements. Engineering model development and test is complete for the technologically difficult altimeter and microwave radiometer instruments. The CDRs for these instruments were both held early in 1998 to support a system-level CDR for the satellite in June 1998. Flight models of the instruments were built during the second half of 1998 for delivery to the payload integration activity at CNES next year. Another

critical activity under way in 1998 was the design and development of the Dual Payload Attach Fitting (DPAF) an addition to the launch vehicle structure that would accommodate the dual Jason/TIMED payload on the Delta II launch vehicle.

CNES held the system-level CDR for the Jason mission with NASA support in the fall of 1998. Simulators or engineering models of all the instruments were delivered to CNES, who will perform platform and payload integration and test as separate activities. The flight models of all the instruments were delivered by September 1999. Satellite-level integration and test began in late 1999. CNES will ship the integrated satellite for Jason to the Western test range and launch is co-manifested with NASA's TIMED space science satellite. Launch was initially scheduled for May 2000 on the Delta Launch vehicle but will be rescheduled for a later date due to CNES satellite and altimeter development problems. After launch and a 60-day checkout, normal mission operations are scheduled to begin, including formation flying with the TOPEX/Poseidon satellite, to provide cross correlation for scientific trend analysis of the sea-surface height.

The ICESat team successfully completed the Mission Design Review (MDR) in December 1998 and the Geoscience Laser Altimeter System (GLAS) Critical Design Review (CDR) in March 1999. The ICESat launch vehicle was selected in April 1999; ICESat is comanifested with the CATSAT mission on a Delta 7320. The Control Center effort was also initiated in FY 1999. Formal review of the GLAS Algorithm Theoretical Basis Document (ATDB) was held in April 1999. Activities for FY 2000 will focus on integration and test of the GLAS flight unit and integration and test of the Ball provided spacecraft. Critical activities for FY 2001 include integration and test of the GLAS instrument with the spacecraft and launch vehicle integration in preparation for launch.

The SOLSTICE and the TSIM missions were merged into one mission called the SORCE. This occurred in FY 1999 after NASA completed an accommodation study, which examined combining various Earth Science missions. It was determined that there were significant science and financial benefits to be gained from combining both the SOLSTICE and TSIM missions. SORCE is a Principle Investigator (PI) Mode mission lead by the University of Colorado's Laboratory for Atmospheric and Space Physics (LASP). During FY 1999, SORCE conducted a successful MDR in May and a Mission Confirmation Review in June. The ESE confirmed SORCE in August and directed the start of the Implementation Sub-phase. Additionally, LASP selected Orbital Science Corporation to provide the spacecraft bus for SORCE in FY 1999. During FY 2000, key milestones will include the spacecraft bus PDR and CDR. The first flight instrument will be completed (XUV Photometer System). The other instruments on SORCE will complete their engineering models and testing, and flight unit fabrication will begin. The launch vehicle for SORCE will be selected in FY 2000.

Two SAGE III instruments were manufactured for long-term monitoring of ozone and aerosol. One instrument was developed and delivered in 1998 and the second one was delivered in early 1999. The instrument will be shipped to Russia the first quarter of 2000, as long as the Russian launch vehicle is ready. The second mission is scheduled to fly aboard the International Space Station in 2003.

The Seawinds CDR was completed in January 1996. The Seawinds instrument continued to undergo protoflight model fabrication and assembly during FY 1998. The Seawinds instrument activities will consist of integration and test of the instrument. The protoflight model is scheduled for delivery to Tsukuba, Japan in March 1999 for a November 2000 launch on the ADEOS II spacecraft by a NASDA H-II rocket from Tanegashima, Japan. However, the project is expecting a second launch delay by Japan of approximately one year.

The Active Cavity Radiometer Irradiance Monitor (ACRIM) made final preparations for launch in FY 1999 including integration of the ACRIM payload onto the Orbital spacecraft and installation of the ACRIM ground station at table Mountain California. ACRIMSAT was successfully launched from Vandenberg Air Force Base (VAFB) on December 20, 1999. The spacecraft was manifested on a Taurus launch vehicle with the Korean Multipurpose Satellite (KOMPSAT). The Mission and Operations Readiness Review and Risk Assessment Review were completed on November 29, 1999 at VAFB. The spacecraft is being operated from the Orbital Sciences Spacecraft Operations Control Center (SOCC) in Dulles, VA for a 45 day on-orbit post launch checkout period after which operations will be handed off to JPL to perform operations for the remainder of the five-year mission.

QuikScat

The QuikScat mission will fill the ocean-wind vector data gap created by the loss of the NASA Scatterometer (NSCAT) on the Japanese Advanced Earth Observing Satellite (ADEOS-I) spacecraft. The NSCAT instrument ceased to function when ADEOS-I failed in 1997. Spares from the follow-on Scatterometer, Seawinds, instrument were used to assemble the QuikScat Scatterometer instrument. Ball Aerospace and Technologies Corporation of Boulder, Colorado was selected in 1997, to provide the QuikScat spacecraft. Ball was selected via the Indefinite Delivery Indefinite Quantity (IDIQ) rapid delivery spacecraft contract. QuikScat was completed in 1998 and launched from Vandenberg Air Force Base on a Titan II in June 1999. QuikScat calibration/validation will be completed in January 2000 and will be delivered to the general science community thereafter.

Landsat-7

The Landsat-7 satellite was launched on April 15, 1999, and declared operational in July 1999. The satellite has been returning excellent images, which meet or exceed NASA's expectations. First data was available to public mid-August 1999. By agreement with the USGS, NASA is operating and funding operations in FY 2000. Beginning in FY 2001, the USGS will operate the Landsat-7 system. The Landsat-7 Government/industry team received the American Institute for Aeronautics and Astronautics award.

EOS Follow-On

NASA ESE is currently developing a science implementation plan, which will drive the selection of EOS follow-on missions. Two of those missions are included in this budget request: NPP and Landsat follow-on.

The NPP preliminary studies were completed in FY 1999 and the project is in formulation leading to an authority to proceed in early 2001. The tentative launch readiness date is late 2005. At present, NASA is responsible for spacecraft development and integration, one instrument, the Advanced Technology Microwave Sounder (ATMS), overall mission integration and science data processing. The IPO is responsible for two instruments, Visible Infrared Imaging Radiometer Suite (VIIRS) and the cross-track infrared sounder (CRIS), ground system development, flight operations and operational data processing.

- The NPP mission: continues filling the EOS 15 year data set for fundamental global climate change observations started by MODIS, AIRS, and a combination of AMSU/MHS/HSB which are the primary instruments on the Terra and Aqua satellites. This is also a precursor mission to the next generation of operational polar weather satellites being developed by the NPOESS Integrated Program Office (IPO), a joint NASA, NOAA, DoD effort. This mission is the result of the ESE extending an invitation to existing and potential satellite operating agencies to join in the development of new remote sensing capabilities that meet both scientific research and operational applications for operational needs. The cost of this mission will be shared between

NASA and the IPO. This arrangement will also help transition these measurements into the future National operational system. ESE will only invest in operational instruments that are co-sponsored by a mission agency, and where there is a clear path for their ultimate integration into the intended operational system(s).

- Landsat follow-on: Continues the basic global land cover change data set. We are hopeful this can be accomplished with a commercial data purchase, and have released a Request for Information as a first step in exploring this avenue.

BASIS OF FY 2001 FUNDING REQUIREMENT

OLD STRUCTURE

EARTH OBSERVING SYSTEM DATA INFORMATION SYSTEM

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Earth Observing System Data Information System.....	261,700	261,906

BASIS OF FY 2001 FUNDING REQUIREMENT

MAJOR DEVELOPMENT

PROPOSED NEW STRUCTURE

EARTH OBSERVING SYSTEM DATA INFORMATION SYSTEM

	FY 1999 OPLAN 12/23/99	FY 2000 PLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Earth Observing System Data Information System.....	[261,700]	[261,906]	252,000

PROGRAM GOALS

The goals for the EOS Data Information System (EOSDIS) are the development and operation of a highly integrated system which can: (1) operate the EOS satellites; (2) acquire instrument data; (3) produce data and information products from the EOS, to preserve these and all other Earth science environmental observations for continuing use; and (4) make all these data and information easily available for use by the research, education, government agencies and all those who can benefit from them in making economic and policy decisions. The EOSDIS facilitates the goals of Earth science by enabling the public to benefit fully from increased understanding and observations of the environment.

STRATEGY FOR ACHIEVING GOALS

The EOSDIS is based on an evolutionary design to develop capabilities with the phased deployment of the EOS satellites and to enable adaptation to changes in user needs and technology. NASA continues to use of prototypes, as appropriate, to assure that EOSDIS will effectively meet the needs of the satellites and users. A limited amount of technology development and adaptation is focused specifically on meeting EOSDIS evolutionary needs while relying on other projects at NASA and other agencies to fund technology development efforts of a more generic nature, e.g., communications technology. An initial version of the system, Version 0, implemented at eight Distributed Active Archive Centers (DAACs) and through cooperative efforts with NOAA, the USGS, and international partner space agencies, became operational in 1994.

Plans for development of subsequent versions of the EOSDIS have been redrawn. Due to continuing problems and schedule delays with completion of the Science Data Processing Segment (SDPS) and the Flight Operations Segment (FOS), two important components of the EOSDIS Core System (ECS), we have focused ECS work on operational support for the near-term missions (Terra and Aqua) and with post-launch deliveries of software restoring some of the originally planned capability.

The EOSDIS development has been divided into six major components: The EOS Polar Ground Stations (EPGS), the EOS Data and Operations System (EDOS – developed by TRW), the EOSDIS backbone Network (EBNet – developed in-house by GSFC), the ECS – under development by Raytheon), the DAACs and Science Investigator-led Processing Systems (SIPS). The EPGS capture spacecraft science data dumps, and forward them to EDOS for processing. The EPGS also provide a telemetry and command link for controlling spacecraft health and safety. The EDOS receives the raw data stream from the satellites, separates the data by instrument, and performs the initial processing (packet restoration and temporal ordering) and back-up archiving. The EBNet delivers the real-time data to and from the operations control centers and the science data to the DAACs. The ECS includes the FOS, which provides data product generation using science software provided by the PIs, for archival, and distribution. The DAACs currently have an operational capability using EOSDIS Version 0 for the non-EOS data and ECS to support Landsat-7. Using the ECS, the DAACs will process the raw data from EOS instruments into useful products, handle all user product searches, requests, and orders and distribute data and information directly to the user community, primarily via the Internet. The DAACs also archive the data and information for future use. Each DAAC focuses on the data needs of a specific segment of the user community. Instrument teams may propose to produce their standard data products operationally and deliver them to the DAACs in lieu of providing the science software for integration and producing the products at the DAACs using ECS. The instrument teams' systems for such product generation are referred to as SIPS. The decision to use SIPS is made case-by-case depending on cost and technical considerations. The EOSDIS Independent Verification and Validation (IV&V) contract is with the Averstar Corporation.

The EDOS element of EOSDIS has been developed and is supporting the launch and operations of the Terra mission. The EDOS interfaces with the TDRSS ground station at White Sands Complex (WSC) and back up EOS Polar Ground Stations (PGS) in Alaska and Norway. The raw satellite data will be sent from the ground stations to the EDOS Level-0 processing center at Space Flight Center (GSFC), which will process the data and send it to the DAACs. EOS missions following Terra will not use the WSC TDRSS ground stations for science data downlink but will reply on the EPGS.

Using the ECS, or DAAC developed systems, the DAACs will process the raw data from the satellites into useful science products, handle user product searches, requests, orders, and distribute data and information directly to the user community. The DAACs also archive Earth science data and information for future use. To better serve the user community, each DAAC focuses on the data needs of a specific segment of the user community. A user-working group (advisory panel) guides each DAAC.

The eight DAACs are located at:

- Alaska Synthetic Aperture RADAR (SAR) Facility, Geophysical Institute. University of Alaska, Fairbanks, Alaska
- Earth Resources Observation System (EROS) Data Center (EDC), U.S. Geological Survey, Sioux Falls, South Dakota
- Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California
- Langley Research Center (LaRC), Hampton, Virginia
- National Snow and Ice Data Center (NSIDC), University of Colorado, Boulder, Colorado
- Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee
- Socio-Economic Data and Applications Center (SEDAC), Lamont-Dougherty Earth Observatory, Columbia University, Palisades, New York
- Goddard Space Flight Center, Maryland

Currently, EOSDIS Version 0 allows direct access to selected pathfinder data holdings from the USGS and NOAA. Relationships with Canada, Japan, Russia, Israel, Australia and several European countries have been established for the exchange of data for EOSDIS. Many multi-agency efforts, in addition to the NASA EOSDIS, are working to improve data availability to the public, especially in the Interagency Working Group on Data Management for Global Change and the Federal Geographic Data Committee.

NASA is currently looking at future data system needs and designs through a variety of paths. The EOSDIS Working Prototype Federation, in its second year, is developing methodologies for decision making and interoperability in a collaborative, yet competitive, distributed data system topology. The Federation consists of 24 Earth Science Information Partners (ESIPs), the eight DAACs and one EOS science computing facility. Twelve ESIPs focus on research, and science data set production and management while the remainder focus on commercial and extended applications for NASA's Earth Science Data. The Federation members collectively are establishing the rules and requirements for membership in the Federation. NASA has also begun long-term planning for the evolution of the current Earth Science data system. A team of Earth and information scientists along with NASA managers has been working on a high-level concept for a new Data Information Systems and Services (New DISS). New DISS refers to the distributed Earth science data system and services which, over the next 6-10 years, will evolve after the EOSDIS. New DISS will consist of a heterogeneous mix of interdependent components derived from the contributions of numerous individuals and institutions. These widely varying participants will be responsible for data management functions including data acquisition and synthesis, access to data and services, and data stewardship. Because the NASA ESE already has made considerable investment in existing data system activities (e.g., DAACs, the ECS, the ESIPs), and in product generation, the near-term NewDISS will necessarily leverage off of these existing components. However, the future NewDISS components could be quite different, as data

systems and services evolve to meet science-driven demands and to take advantage of technological innovation. The report from the New DISS planning team will be produced in 2000.

SCHEDULE AND OUTPUTS

EOSDIS Version 1 Plan: January 1997 Revised: Replaced	Provide support for science data processing, archival, and management of the data from the two EOS instruments operating on the TRMM spacecraft. The ECS contractor failed initial test readiness for EOSDIS Version 1 and NASA issued a Stop Work Order. Replacement systems were developed at GSFC and LaRC, (extended "Version 0" in-house system), and the systems are performing successfully.
EOSDIS Version 2 Plan and actual: January 1999 through December 1999	Provide support the launch of Terra and Landsat-7. Technical difficulties by the ECS contractor have required a descope in the original requirements planned for Version 2. NASA issued a Change Order to Raytheon for reduced requirements set (A+). The requirements were provided in a set of incremental deliveries beginning in January 1999 and ending in December 1999.
EOSDIS Version 3 Plan: June 2000 Revised: December 2000	Provide science processing and flight operations support for Aqua and ICESat. Will support flight operations and science processing.
EOSDIS Version 4 Plan: December 2000 Revised: April 2001	Provide science processing and flight operations support for Chemistry. Will support flight operations and science processing. Provides final increment of ECS A+ requirements.

Providing broad and efficient access to data products is key to meeting the Agency mission of advancing and communicating scientific knowledge. The successful functioning of EOSDIS is essential to the accomplishment of all three of Earth science's strategic goals. EOSDIS has been routinely providing and will continue to provide Earth science data products to end-users within five days of receipt or production of the requested data product. These products comprise data from currently operating space assets including: precipitation measurements and observations of tropical storm from the Tropical Rainfall Measurement Mission (TRMM), ocean productivity measurements from the Sea-viewing Wide Field-of-view Sensor (SeaWifs), detection of ocean surface height changes used to predict El Nino occurrence and strength from the Topex/Poseidon Mission, and sea ice motion and Antarctic mapping from Canada's RADARSAT. The data provided also include: measurements of stratospheric trace chemicals from the Upper Atmospheric Research Satellite (UARS), Antarctic Ozone Hole measurements from the Total Ozone Mapping System (TOMS), land use and land cover data from the heritage Landsat missions, and measurements of the earth and solar radiation from the Earth Radiation Budget Experiment (ERBE).

Some key indicators of DAAC performance are the volume of data archived (approximately 284 terabytes at the end of FY 1999), the number of users accessing the DAACs (just under 1.3 million distinct users accessed the DAACs in FY 1999), and the number of data products delivered in response to user requests (approximately 5.2 million data products delivered in FY 1998). Metrics will also be

tracked that capture the degree of user satisfaction, which will provide ESE with information that shows how well we are meeting customer expectations in providing data.

ACCOMPLISHMENTS AND PROPOSED RESULTS

The ECS FOS supported a December 1999 launch of the Terra spacecraft after the successful replacement of deficient real time command and control software with a Raytheon developed spacecraft control system called "Eclipse". The Eclipse software has been integrated with the other components of the FOS system as well as other elements of the EOS ground system, and has been extensively tested and exercised during a number of tests with the Terra spacecraft and instruments during FY 1999. The FOS Instrument Support Toolkits (ISTs), which allow instrument operations teams to plan for the operation of their instruments and monitor instrument performance from their home institutions, were installed at the primary operations sites for the Terra instrument teams.

Development of the ECS SDPS has stabilized this year. The baseline system for support of Landsat-7 and Terra was deployed to the GSFC, LaRC, EDC and NSIDC DAACs. Extensive ground system testing was conducted in preparation for the Landsat-7 launch. Landsat-7 data ingest, archival and distribution operations were initiated at the EDC DAAC, utilizing the ECS, shortly after launch in April 1999. The DAAC began distributing data to the general public in September 1999. Extensive testing and operations readiness activities have also been underway in preparation for the Terra launch. A series of progressively longer and more operationally complex system end-to-end tests were conducted, beginning in January 1999 with 24 hour tests to verify system performance requirements, and concluding in October 1999 with a successful 5 day Terra mission operations simulation involving all science system components. During 1999, requirements for higher level MODIS instrument data processing (Level 2 and 3 products) were transferred to the MODIS science computing facility, which became the first operational "SIPS". The higher level products will still be archived and distributed by the GSFC, EDC and NSIDC DAACs. The CERES Instrument Team has also opted to process, archive and distribute their data from the same LaRC DAAC system developed to support CERES on TRMM.

The ECS Science and Flight Operations Systems were both verified to be compliant with Y2K this year.

The EOSDIS will continue to work to meet its planned performance target of successfully disseminating Earth science data to enable our science research and applications goals and objectives. Indicators of this activity will be making available acquired observations and information on land surface, and climate to users within 5 days of acquisition and improving on prior year targets for archive, distribution and number of customers served.

The ECS contract has been restructured, scaling back on some lower priority requirements, and adding new requirements for support of future missions such as Aqua, ICESat, and Chemistry. The Raytheon proposal was evaluated, and negotiations were conducted during this year. A sound cost and schedule baseline has been established, on which the contractor's future performance will be measured.

Other elements of EOSDIS needed to support the Terra mission continued on schedule. The EDOS and the EBNET were delivered and are ready to support command uplink and data acquisition for the Terra Mission. The GSFC and LaRC DAACs have successfully supported science processing and data management for the CERES and LIS instruments on TRMM since the TRMM launch in November 1997.

The EOSDIS Federation experiment continued for its full year in 1999. The 24 Working Prototype Earth Science Information Partners (WP-ESIPs) have been developing science products, collaborating with one another as a single entity and in "clusters" and collective management and data set interoperability. The 24 WP-ESIPs, along with the DAACs, and the science computing facility members of the Federation experiment, represent the broad science and applications community and include representatives from educational, industry, regional governments and consortium, and NASA data centers. Implementation of the federation is being carried out in parallel with the development of EOSDIS and the DAACs

NASA began long-term planning for the evolution of the current Earth Science data system in FY 1999. A team of Earth and information scientists along with NASA managers began work on a high-level concept for a new NewDISS which will evolve from the current EOSDIS, working prototype Federation research, and other ESE mission data systems.

A key focus in 1999 was the review of the eight DAACs by the National Research Council (NRC). The NRC reviewers visited each DAAC and assessed its effectiveness through interviews with DAAC customers. NRC is currently finalizing their report on the DAAC peer review. The NRC released a preliminary report in early FY 1999 and NASA and the DAACs have been reviewing the report and responding to NRC recommendations. Overall, the review was laudatory of the DAACs and the EOSDIS system and provided some very insightful recommendations for improving the DAACs support for Earth science.

In 2000, the ECS Science System will be upgraded to improve user interface services, add capabilities required for support of Aqua instruments, increase system capacity, and upgrade to newer versions of COTS products. A Performance Verification Center (PVC) will be established to provide an environment for testing performance of new releases, prior to deployment to operational DAACs. Major releases are planned in April and December 2000.

The Federation Experiment and the WP-ESIPs will continue their important collaboration in 2000, the final year for the experiment. The Federation will develop a constitution and by-laws outlining the rules and requirements for membership in the Federation. The WP-ESIPs will be busy completing their science data set productions and achieving smooth operations as a federation. NASA will complete their evaluation of the experiment and decide on the feasibility and strategy for evolving EOSDIS into a federated architecture.

A key milestone for 2000 will be NASA ESE response to the NRC report on the peer review of the ESE DAACs. A NASA management team will finalize their evaluation of the report and make recommendations to the NRC and to the Associate Administrator for Earth science.

ESE will continue tracking the three key indicators of DAAC performance. In FY 2001 the volume of data archived will increase by 20% compared to FY 2000 (targeting approximately 442 terabytes). The number of users accessing the DAACs will increase by 20% compared to FY 2000 (targeting approximately 1.5 million). The number of data products delivered in response to user requests will increase by 10% compared to FY 2000 (targeting approximately 5.4 million data products delivered).

In FY 2001, operations and completion of the EOSDIS will be the primary tasks. Additional EOSDIS Core System (ECS) software deliveries in FY 2001 to support the requirements for the Aqua, Chemistry, and ICESat missions. Higher level processing of the science data products from Aqua and Chemistry will be accomplished at the DAACs or by the instrument science teams at their institutions as appropriate, while the EOSDIS DAACs will provide data archival, distribution, and user support. Additional

EOSDIS functionality will be delivered to further automatic operations and user services. A key focus will be on implementing a new, web-based user search and order interface.

BASIS OF FY 2001 FUNDING REQUIREMENT

OLD STRUCTURE

EARTH PROBES

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Total Ozone Mapping Spectrometer	9,900	24,800
Earth System Science Pathfinders	62,300	94,500
VCL	19,700	21,300
GRACE	30,300	24,800
PICASSO-CENA	5,000	25,200
CloudSat	2,000	19,300
Volcam alternate mission	100	400
Program Support/Future missions	5,200	3,500
Experiments of Opportunity	2,100	1,000
Triana	35,000	35,100
University Class Earth System Science	--	2,000
Total	109,300	157,400

BASIS OF FY 2001 FUNDING REQUIREMENT

MAJOR DEVELOPMENT

PROPOSED NEW STRUCTURE

EARTH PROBES

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Total Ozone Mapping Spectrometer	[9,900]	[24,800]	500
Earth System Science Pathfinders	[62,300]	[94,500]	105,900
VCL	[19,700]	[21,300]	2,600
GRACE	[30,300]	[24,800]	8,900
PICASSO-CENA	[5,000]	[25,200]	35,400
CloudSat	[2,000]	[19,300]	49,800
Volcam alternate mission	[100]	[400]	--
Program Support/Future missions	[5,200]	[3,500]	9,200
Experiments of Opportunity	[2,100]	[1,000]	500
Triana	[35,000]	[35,100]	2,000
University Class Earth System Science	--	[2,000]	11,500
Shuttle Radar Topography Mission	--	[6,200]	--
Total	[109,300]	[163,600]	120,400

Note: SRTM has been added to the proposed new structure.

PROGRAM GOALS

The Earth Probes program is the component of Earth science that addresses unique, specific, highly focused mission requirements in Earth science research. The program was designed to have the flexibility to take advantage of unique opportunities presented by international cooperative efforts, small satellites and advanced technical innovation, and to complement the Earth Observing System by providing the ability to investigate processes that require special orbits or have unique requirements on short development cycle of 1-3 years. The currently approved Earth Probes missions are the Total Ozone Mapping Spectrometer (TOMS), Triana, and Earth System Science Pathfinders (ESSP) missions. NASA has added the University Class Earth System Science (UnESS) pathfinders to the Earth Probes program.

STRATEGY FOR ACHIEVING GOALS

TOMS

The scientific objectives of the TOMS project are to measure the long-term changes in total ozone and to verify the chemical models of the stratosphere used to predict future trends. The TOMS flights build on the experience that began in 1978 with the launch of a TOMS instrument (flight model 1) on Nimbus-7 and continued with the TOMS instrument (flight model 2) on a Russian Meteor-3, launched in 1991, a TOMS (flight model 3) launched on the Japanese ADEOS in 1996 and the Earth Probe spacecraft also launched in 1996. The remaining development TOMS project consists of one instrument (flight model 5, designated FM-5). The FM-5 has been completed, and was scheduled to fly as a cooperative mission with Russia in late 2000. However, Russia has indicated that it cannot meet that launch date. Presently, the Agency has completed its re-planning and will fly FM-5, as QuikToms, on a US vehicle and spacecraft in August 2000.

ESSP

The ESSP is a science-driven project intended to identify and develop in a short time, small satellite missions to accomplish scientific objectives in response to national and international research priorities not addressed by current projects. ESSP will provide periodic "windows of opportunity" to accommodate new scientific priorities and infuse new scientific participation into the Earth science program. By launching ESSP missions on a regular basis, NASA will provide a mechanism by which pressing questions in Earth system science may be addressed in a timely fashion, permitting a continual improvement in our understanding of the Earth system and the processes that affect it.

The first two ESSP missions and an alternate mission were selected in March 1997. The Vegetation Canopy Lidar (VCL) mission led by a University of Maryland, College Park Principal Investigator, with spacecraft and instrument delivery expected in early 2000 and a scheduled launch date of September 2000. The second mission, Gravity Recovery and Climate Experiment (GRACE) which is led by a Principal Investigator from the University of Texas at Austin with significant participation by the German Aerospace Center (DLR), completed formulation and has begun its implementation with launch expected in June 2001. A minimum amount of funding was provided to the Chemistry and Circulation Occultation Spectroscopy Mission (CCOSM) to maintain this mission as an alternate to replace VCL or GRACE if significant difficulties developed. Given that the first two ESSP missions are in the implementation sub-process, CCOSM has been discontinued as an alternate mission. A final CCOSM report has been provided to NASA.

The second ESSP Announcement of Opportunity (AO) was released in the third quarter of FY 1998. The Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations – *Climatologie Etendue des Nuages et des Aerosols* (PICASSO-CENA) mission was selected in December 1998 is led by NASA's LaRC and is scheduled for launch in 2003. PICASSO-CENA is designed to address the role of clouds and aerosols in the Earth's radiation budget. It will employ innovative Light-Detection and Ranging (LIDAR) instrumentation to profile the vertical distribution of clouds and aerosols, while another instrument will simultaneously image the infrared emission of the atmosphere. During the daylight half of its orbit, PICASSO-CENA will measure the reflected sunlight in an oxygen absorption band and take images of the atmosphere with a wide-field camera. The total estimated mission cost of PICASSO-CENA, including launch vehicle, is $168.3 million, of which NASA will provide $112.2 million. The remaining funding is contributed through the French Space Agency for the spacecraft bus. PICASSO-CENA will be launched in 2003. It consists of a partnership between the LaRC, France's Centre Nationale D'Etudes Spatiale (CNES), the Institute Pierre Simon LaPlace, Hampton University of Hampton, Virginia (a Historically Black University), the Ball Aerospace and Technology Corporation and the GSFC and the KSC. France is providing a PROTEUS spacecraft, the infrared imaging system, and science analysis support.

In addition, NASA chose two additional missions, CloudSat and the Volcanic Ash Mission (VOLCAM), for further study in December 1998. Based on the study results completed in March 1999, NASA has selected CloudSat for full development as an ESSP AO#2 mission. VOLCAM was selected as the alternate mission. CloudSat is a two-year data set pathfinder mission designed to advance the understanding of the cloud-climate feedback problem. The mission is focused on understanding the role of optically thick clouds on the Earth's radiation budget using advanced cloud-profiling radar. CloudSat has been dual manifested with the PICASSO-CENA mission on a Delta launch vehicle scheduled for launch in 2003. CloudSat is collaboration between the United States, Canada, Germany, and Japan, and is managed by the JPL. It consists of a partnership between JPL, Colorado State University, the Canadian Space Agency (CSA), Ball Aerospace, the U.S. Department of Energy, the U.S. Air Force, the GSFC and the KSC. The total estimated mission cost of CloudSat, including launch vehicle, is $140.8 million, of which NASA will provide $115.8 million. The remaining funding is contributed through the Department of Energy for calibration efforts, the US Air Force for ground operations, and Canada for instrument components. NASA intends to solicit another set of ESSP missions in calendar year 2000.

Experiments Of Opportunity

This project offers a capability to undertake short duration flights of instruments on the Space Shuttle and other platforms. The ESE has used the capability of Shuttle/Spacelab development in the important areas of design, early test and checkout of remote sensing instruments for free flying missions, and short-term atmospheric and environmental data gathering for scientific analysis. Instrument development activities have supported a wide range of instrumentation, tailored for Space Shuttle and airborne missions.

Triana

The Triana mission is an Earth observation spacecraft to be located at the Sun-Earth L1 point providing a near-term real time, continuous high definition color view of the full sun-lit disc of the Earth.

During 1998 the mission was studied at GSFC and an AO was released by NASA Headquarters in July soliciting proposals for full Triana mission implementation**.** A selection was made in November for the Scripps Institution of Oceanography to build and conduct the Triana mission. Triana will carry the Earth Polychromatic Imaging Camera built by Lockheed Martin Advanced

Technology Company, a radiometer built by the National Institute of Standards and Technology, and a plasma magnetometer that measures solar wind built by GSFC and the Massachusetts Institute of Technology. The Triana mission has suspended work per Congressional direction, while the National Academy of Science (NAS) conducts its review of the scientific aspects of the mission.

UnESS

UnESS consists of Spaceborne investigations of modest science scope. These investigations will be lead by U.S. University principal investigators with significant student involvement. The Announcement of Opportunity was released in August 1999, and is expected to lead to an award of up to six Phase A studies. These studies are expected to result in the selection of a maximum of two missions for implementation and expected launch in 2003.

SRTM

The Shuttle Radar Topography Mission (SRTM) is a reimbursable mission with the National Imaging and Mapping Agency (NIMA). In FY 2000, NASA has requested funding for costs associated with cost growth. The SRTM is planned for launch in January 2000.

SCHEDULE AND OUTPUTS

Launch Readiness dates – verifies that the system elements constructed for use, and the existing support elements, such as launch site, space vehicle and booster, are ready for launch.

TOMS FM-5 (QuikToms)
Plan: August 2000

Vegetation Canopy Lidar
Plan: May 2000
Revised: September 2000

The VCL, the first ESSP mission, is scheduled to launch in September 2000. The later launch date relative to the plan reflects the delay in initially selecting and contracting the first ESSP missions, the change in VCL launch vehicle from a Pegasus to an Athena, and delays in instrument and spacecraft bus development.

Triana
Plan: December 2000
Revised: First quarter 2001

Congressional mandated launch delay. The Triana mission has suspended work while the NAS conducts its review of the scientific aspects of the mission.

Gravity Recovery and Climate Experiment
Plan: June 2001

PICASSO-CENA
Plan: Second Quarter, 2003

CloudSat
Plan: Second Quarter, 2003

ACCOMPLISHMENTS AND PROPOSED RESULTS

TOMS

The TOMS FM-5 has been completed, and was scheduled to fly as a cooperative mission with Russia in late 2000. However, Russia has delayed this mission until the year 2002 or later due to funding problems. Presently, the Agency has completed its re-planning and will fly FM-5 on a US vehicle and spacecraft in August 2000. This will meet the need of a gap-filler mission to continue acquisition of the Total Ozone data set. This mission is called QuikToms and is currently in the implementation sub-process and completed the mission design review (MDR) in September 1999.

ESSP

The first ESSP AO was released in FY 1996 and the selection occurred in March 1997. The first two missions**,** VCL and GRACE**,** are currently in the implementation sub-process phase with scheduled launches in September 2000 and June 2001 respectively. The second ESSP AO was released in FY 1998 and the selections occurred in December 1998 and March 1999. The second two missions PICASSO-CENA and CloudSat are currently in the formulation sub-process phase leading to mission confirmation in 2000. CloudSat has been dual manifested with the PICASSO-CENA mission on a Delta launch vehicle scheduled for launch in 2003. VOLCAM is in the pre-formulation sub-process as an alternate ESSP mission.

Experiments of Opportunity

The Experiments of Opportunity Program is the funding source for NASA's participation in the *Satellite de Applicaciones Cientificas-C* (SAC-C) mission. SAC-C is a joint mission between NASA and the Argentine Space Agency (CONAE). The mission is co-manifested with NASA's New Millennium Earth Orbiter-1 mission and is scheduled for an early 2000 launch. NASA is providing launch vehicle, scalar helium magnetometer and GPS receivers. The Argentines have various instruments such as multispectral scanner, and high-resolution camera, etc. Spacecraft thermal and structural models were tested and qualified in 1998. The magnetic mapping payload has been calibrated as well. SAC-C has completed fabrication, integration and test of the spacecraft and payloads. The mission will be in operation in the year 2000.

UnESS

The UnESS AO was released in August 1999, and is expected to lead to an award of up to six phase-A studies by March 2000. These studies are expected to result in the selection of at least two missions for implementation and expected launch in 2003.

BASIS OF FY 2001 FUNDING REQUIREMENT

OLD STRUCTURE

APPLIED RESEARCH AND DATA ANALYSIS

	FY 1999 OPLAN 12/23/99	FY 2000 PLAN REVISED
	(Thousands of Dollars)	
Earth Science Program Science	323,600	359,404
Operations, Data Retrieval and Storage	76,100	77,100
Total	399,700	436,504

BASIS OF FY 2001 FUNDING REQUIREMENT

PROPOSED NEW STRUCTURE

RESEARCH AND TECHNOLOGY

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
	(Thousands of Dollars)		
Earth Science Program Science	[251,800]	[286,300]	353,200
Applications, Commercialization and Education	[82,900]	[85,704]	69,200
Technology	[103,500]	[96,415]	110,900
Construction of Facilities	[1,500]	[1,000]	--
Total	[439,700]	[469,419]	533,300

Note: Earth Science Program Science in FY01 has been broken out to reflect the distinction between the Research Program and the Applications, Commercialization and Education (ACE) Program. GLOBE after FY00 has been included under the ACE program. Detail of this content is provided in each of the element subsections below. The Mission Operations section of Operations, Data Retrieval and Storage is now shown separately under Mission Operations.

PROGRAM GOALS

The goal of Research and Technology is to advance our understanding of the global climate environment, the vulnerability of the environment to human and natural forces of change, and the provision of numerical models and other tools necessary for understanding global climate change.

STRATEGY FOR ACHIEVING GOALS

The Research and Technology program is divided into three components:

- Research that supports basic Earth science research, analysis, and data analysis of related EOS and other mission science data. Included is the suborbital science program of crewed aircraft and uninhabited aircraft available to researchers and PIs. The EOS interdisciplinary science consists of focused research centered on a specific Earth science data set and geared toward a broader probe into Earth science systemic functions. Also included are funding for high performance computing and communications, and the provision of computing infrastructure.

- Applications, Commercialization, and Education that supports applications research (e.g., natural hazards, agriculture, disaster management, etc.) and the transfer of knowledge through outreach and education. The Commercial Remote Sensing Program that funds cooperative efforts with industrial partners aimed at enabling development of a viable commercial remote sensing industry.

- Earth Science advanced technology that supports development of key technologies to enable our future science missions by reducing their development time and cost.

Each of the major components of Research and Technology has its own set of goals, strategies for achieving goals, performance measures, and accomplishments and plans.

BASIS OF FY 2001 FUNDING REQUIREMENT

OLD STRUCTURE

EARTH SCIENCE PROGRAM SCIENCE

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Airborne Science and Applications	18,100	22,100
Uncrewed Aerial Vehicles (UAV)	1,900	4,000
Commercial Remote Sensing	38,100	30,400
Mission Science Teams	48,100	55,800
EOS Science	46,400	60,300
R&A	161,600	174,600
Education	9,400	12,200
Total	323.600	359,400

BASIS OF FY 2001 FUNDING REQUIREMENT

RESEARCH AND TECHNOLOGY

PROPOSED NEW STRUCTURE

EARTH SCIENCE PROGRAM SCIENCE

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Research and Analysis – Science	[136,000]	[141,800]	163,600
EOS Science	[41,600]	[55,000]	52,200
Mission Science Teams - Research	[48,100]	[55,800]	100,000
Airborne Science and Applications	[18,100]	[22,100]	22,700
Uncrewed Aerial Vehicles (UAV)	[1,900]	[4,000]	5,000
Information Systems	[6,100]	[7,600]	9,700
Total	[251,800]	[286,300]	353,200

Note: Earth Science Program Science in FY01 has been broken out to reflect the distinction between the Research Program and the Applications, Commercialization and Education (ACE) Program. These changes are reflected in realignment of the following areas to the ACE program: applications portion of R&A, the fellowships portion of EOS Science, and the Commercial Remote Sensing Program. A description of these activities is located in the ACE narrative section.

PROGRAM GOALS

The goal for the Earth Science Research program is to contribute to the integration of the Earth and environmental sciences into an interdisciplinary scientific understanding of the Earth system and the effects of humankind on the global environment. Major emphasis is placed on providing early warning and fast response to global environmental changes that pose risks to society. The science program provides the analysis and integration of critical data and models needed for national and international assessments.

STRATEGY FOR ACHIEVING GOALS

The Research and Analysis (R&A) science project is essential to the discovery of new concepts and to the design of future missions. The primary mode of research coordination occurs through the USGCRP, the Committee on the Environment and Natural Resources (CENR) Subcommittee on Global Change Research, and the various boards and committees at the National Academies of Sciences. NASA manages the R&A budget according to five areas: Ecosystems and the Global Carbon Cycle, Global Water and Energy Cycle, Climate Variability and Prediction, Atmospheric Chemistry, and Solid Earth and Natural Hazards. The Natural Hazards portion of this latter area is addressed under the Applications, Commercialization and Education program. Overall science questions are being developed in the Science Implementation Plan.

The Science strategy of interdisciplinary research is to increase scientific understanding of the global environment and its vulnerability to both human and natural factors of change (e.g. pollution, climate variability, deforestation). Viewing the Earth from space is essential to comprehending the cumulative influence of human activities on its global natural resource base. An important priority is to provide accurate assessment of the extent and health of the world's forest, grassland, and agricultural resources. Observations from space are the only source of objective information on the human use of land in a time of rapid land use development. Another priority is to improve understanding and prediction of transient climate variation, such as El Niño anomalies and to characterize and understand the effects of such variations on the terrestrial and oceanic biosphere. Reducing uncertainties in climate predictions a season or a year in advance would dramatically improve agriculture and energy utilization planning. There is increasing evidence that predictions of extreme weather events can be improved by understanding their links to interannual climate phenomena like El Niño events. Special attention is being given to measuring and modeling the effects of climate forcing factors like clouds, solar radiation, aerosols and greenhouse gases in order to improve our assessments of climate trends on time scales of decades to centuries. There is also appreciable effort going into identifying those processes that couple the biosphere and climate. A continuing priority is to understand the causes and consequences of changes in atmospheric ozone and the feedback processes between atmospheric chemical and climate change. Emphasis is also placed on the changing composition of the lower atmosphere, which is sensitive to the unprecedented increase of pollutant emissions in rapidly developing regions throughout the world.

EOS science consists of research aimed to assure that the EOS data can be accurately validated to ground, airborne, and other space-based measurements and interdisciplinary investigations geared for a broader probe into Earth science system functions. The former is needed to assure the quality of data produced by EOS instruments, many of which will be producing the first space-based data of their type, while the latter are needed to assure creative use of multiple data types together with research models to address questions associated with the linkage between Earth system components.

The objectives of the mission science team/guest investigators are to analyze data sets from operational spacecraft that support global climate change research in atmospheric ozone and trace chemical species, the Earth's radiation budget, aerosols, sea ice, land surface properties, and ocean circulation and biology.

The airborne science project funds operations of two ER-2s, one DC-8 aircraft, and one P-3B. The project funds operation and support of a core of remote sensing instruments and a facility for analyzing and calibrating data from those instruments. The specially modified aircraft serve as test beds for newly developed instrumentation and their algorithms prior to space flight. The instrumented aircraft provide remote sensing and *in situ* measurements for many Earth science research and analysis field campaigns in all ESE science areas throughout the world. The ER-2 aircraft, in particular, are unique in that they fly well into the stratosphere and were key in collecting *in situ* data for our understanding of ozone depletion and stratospheric transport mechanisms. One of these provided support and observations, including over flights of hurricane *Georges*, for an interagency experiment designed to improve our capability to predict hurricane landfall and intensity. The DC-8 aircraft provides a unique "flying laboratory" facility for a broad range of disciplines in atmospheric sciences. The P-3B is used mainly for lower altitude operations. Many process-oriented studies involve the use of two or more aircraft together with ground and or balloon-based instruments.

NASA is implementing an Uninhabited Aerial Vehicle (UAV) science demonstration program in order to provide an opportunity for the Earth science research and applications communities to utilize UAVs in a small number of missions over the next few years. This demonstration program should help to provide experience in the scientific use of UAVs under a variety of operating environments and conditions such as flights of 24 hours and longer duration, higher altitudes at subsonic speeds, and flights in environments hazardous to the onboard pilot in traditional aircraft. Examples of missions enabled by UAVs are those to observe diurnal changes of key atmosphere, oceanic and land surface processes, or missions to observe key Antarctic or volcanic phenomena which have been inaccessible for pilot safety reasons.

The Earth science information system project has been structured to provide a balanced system of high performance computers, mass storage systems, workstations, and appropriate network connectivity between researchers and components of the system. A major portion of the project funding supports operation of a supercomputing center (the NASA Center for Computational Sciences) at GSFC. A full range of computational services is provided to a community of approximately 1,400 users representing all disciplines of Earth and space sciences. Users of the supercomputer complex select representatives to an advisory committee who are integrally involved in strategic planning for the evolution of the complex. They provide feedback on user satisfaction with services provided and help establish priorities for service and capacity upgrades. Offsite NASA-sponsored users comprise 25% of the total. The project monitors and participates in advanced technology projects, such as the HPCC program and National Science Foundation's gigabit test bed programs. Project elements at GSFC and JPL are focused on providing early access to emerging technologies for the Earth and space science communities. The early access to new technology provides the project with the opportunity to influence vendors and system developers on issues unique to the Earth and space science researchers such as data intensive computation and algorithm development. Early access also prepares a subset of the research community to make changes in research methodology to exploit the new technologies and to champion promising technologies to their colleagues and peers.

SCHEDULE AND OUTPUTS

The scientific issues of concern to Earth science are among the most complex and policy relevant of any major scientific research program. The results of Earth science program science are critical to the development of sound U. S. and global environmental policy, necessary for long-term sustainable development. Each of the science theme areas discussed in the accomplishments and plans section describe performance targets to ensure that the goal and objectives of the Earth science program science are met. A summary schedule and outputs relating to management, business practices, and bases for comparisons applicable to the whole Earth science program are in the table below.

Research (Natural hazards included in FY99 and FY00)	FY 1999 Estimate/Actual	FY 2000 Estimate	FY 2001 Estimate
Number of principal investigators	1,100/1,123	1,100	1,160
Number of research tasks under way	1,525/1,662	1,525	1,580
Average duration of research tasks	3 years	3 years	3 years
Number of science solicitations released	21/7*	12	12
Number proposals received	975/1,327	1,125	1,300
Number of proposals rated very good to excellent	525/pending	550	530
Number of proposals selected	355/pending	360	360
Time to process proposal (selection through obligation)	45 days	30 days	30 days
Number of days until funding is released	Simultaneously with award	Same	Same
Percent of R & A funding obligated:			
Current Budget Authority:	87%/91%	100%	100%
Prior Budget Authority:	100%	100%	100%
Percent of program reviewed by science peers	95%	95%	95%

* Estimate revised due to consolidation of solicitations.

ACCOMPLISHMENTS AND PROPOSED RESULTS

Research & Analysis -- EOS Science

In FY 1999, continuing into FY 2000 and FY 2001, the following are significant accomplishments in the areas of Ecosystems and the Global Carbon Cycle, Global Water and Energy Cycle, Climate Variability and Prediction, Atmospheric Chemistry, and EOS Science.

Ecosystems and the Global Carbon Cycle: determining how land cover and climate changes affect agricultural productivity and ecosystem health

The carbon cycle is one of the major Earth system processes influencing global climate. NASA research on the biology and biogeochemistry of ecosystems and the global carbon cycle aims to understand and predict how terrestrial and marine ecosystems are changing. This research theme addresses ecosystems as they are affected by human activity, as they change due to their own intrinsic biological dynamics, and as they respond to climatic variations and, in turn, affect climate. Emphasis is on

understanding the processes of the Earth system that affect its capacity for biological productivity and the role of the biosphere in Earth system function. Understanding the distribution and cycling of carbon among the active land, ocean, and atmospheric reservoirs constitutes a major scientific focus for research.

Accomplishments

Research in FY 1999 advanced models of carbon uptake by terrestrial and marine ecosystems, created quantitative satellite data products, and yielded new understanding of ecosystem processes important for carbon cycling. A second generation of coupled physical-biological ocean models was produced through the Joint Global Ocean Flux Study Synthesis and Modeling Program. Inter-comparisons of a suite of models of terrestrial productivity bounded the upper and lower limits of ecosystem response to changes in global climate, atmospheric carbon dioxide concentration, and land cover change. The Sensor Inter comparison and Merger for Biological and Interdisciplinary Ocean Studies (SIMBIOS) project has developed algorithms to interrelate and compare data sets from different ocean color scanners (emphasizing the Sea Wide-Field-of-View Sensor [SeaWifs]); these algorithms are being used to merge data sets and produce more comprehensive information about global ocean productivity. Satellite-derived evidence of a global ocean productivity response to conditions and of the positive effects of iron fertilization on ocean productivity were published in the open literature, and the measurement of the distribution of different types of phytoplankton was demonstrated. New data products quantifying global tree cover percentage were created using space-based observations as first step toward improving estimates of aboveground carbon storage in global forests. These data products will be used to help quantify carbon storage in the ocean. Resource managers and the fishing industry will also be able to use them to track productivity patterns in the coastal ocean and make decisions about resource management and where to deploy fishing vessels. The studies of iron fertilization will yield an assessment of the potential of for certain regions of the ocean to sequester more carbon than they currently do.

Analysis of carbon uptake and emission data for the Boreal Ecosystem-Atmosphere Study (BOREAS) in Canada and the Northern U.S., and other field studies that employed several differing methodologies (e.g., eddy covariance flux towers, aircraft-based flux measurements, traditional inventory methods, and inverse atmospheric modeling) highlighted important discrepancies among the measurement approaches. This has set the stage for simple tests to reconcile or resolve the differences and, as a direct result, reduce major uncertainties in estimation of regional carbon dioxide fluxes. The results of this research will help to quantify the size of the Northern Hemisphere carbon sink and significantly reduce the error range surrounding it.

The Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) drew attention to the effects of low levels of selective logging and understory biomass burning (burning that disturbs the forest, but does not significantly modify the forest canopy) on the occurrence of significant carbon losses from tropical forest ecosystems. This carbon loss is unaccounted for in current carbon budget analyses for the region and has traditionally been difficult to detect using conventional satellite data analysis approaches. This information will help to quantify the South American carbon source due to forest clearing and disturbance and significantly reduce the error range surrounding it. It will also be used to improve estimates of the total area of tropical forest impacted by land use change.

For the terrestrial biosphere, a new data product showing the distribution of global tree coverage was prepared, making use of data from the Advanced Very High Resolution Radiometer (AVHRR) series of instruments. These observations serve as a first step toward improving estimates of aboveground carbon storage in global forests. Such estimates should be dramatically improved when

Vegetation Canopy Lidar (VCL) data become available late 2000. These results will be used to quantify aboveground biomass in rapidly changing parts of the world and, therefore, reduce uncertainties in the amount of carbon sequestered in certain forests recovering from disturbance.

The Landsat 7 satellite was launched successfully on April 15, 1999, and Mission Operations is acquiring 90,000 scenes per year. High quality data distribution began on August 23, 1999, and public announcement was made on August 30, 1999. Seasonal image collection to refresh the global archive began in July 1999, and over 50,000 acquisitions were archived. There has been one global acquisition and a partial refresh in FY 1999. A rate of 2-3 global terrestrial acquisitions a year will be achieved after a full year of operation. Research is underway to quantify the spatial extent of land cover change in global hot spots of land conversion and improve calculations of carbon emissions. This information can be used to create accurate maps of global land cover and quantify rates of change. Land resource managers will used these data products to monitor and manage their lands. Scientists assessing carbon storage in terrestrial ecosystems will use these data to stratify the land surface into categories of carbon uptake or release.

Orblmage is providing SeaWifs data distribution to the science community through a commercial data buy. SeaWifs project has been producing routinely, near-daily global maps since Sept. 1997. In addition to its primary product of ocean color, SeaWifs has also been producing data on the terrestrial biosphere, sediments transport and water-covered regions, and atmosphere aerosols. The launch of Moderate Resolution Imaging Spectroradiometer (MODIS) on Terra will add new information about primary productivity and will greatly improve spatial coverage over that available from SeaWifs. The SIMBIOS project will merge ocean color data from various sensors and thus a consistent time series of ocean color will be established. This information can be used to estimate global ocean productivity and to assess fisheries production and pollution impacts in coastal regions. Analysis of time series of these productivity data will yield improved estimates of coastal carbon uptake and sequestration for various regions of the ocean and may help to locate and quantify the southern ocean carbon sink(s).

Plans

In FY 2000 the SIMBIOS project will merge MODIS ocean color data into the global ocean color time series that began with Ocean Color Temperature Sensor (OCTS) and SeaWifs. Multi-year time series of ocean color data will be used to understand and predict the response of marine ecosystems to climate change. ESE will continue the ocean color time series with 60% global coverage every four days. This will allow continued monitoring of global ocean productivity and identification and quantification of the ocean carbon sink(s).

NASA contributions to the First National Assessment of the Potential Consequences of Climate Variability and Change will be completed. These will include production of the climate scenario information, support of the National Synthesis, several of the U. S. regional analyses, and supporting research for several U. S. studies. We will participate in the Southern African Regional Science Initiative-2000 (SAFARI-2000) international assessment in Southern Africa. This assessment will quantify the effects of climate variability and management practices on the environment, as well as provides significant information on the transfer of carbon between the atmosphere and the vegetated land surface. This information can be used by land managers to manage the resources on their lands. The information provided for the National Assessment will be used to improve predictive models of land cover change and its impacts on natural resources and environmental quality within the U.S. Scientists and policy-makers will use the data from the SAFARI 2000 campaign to quantify the annual carbon emissions from southern Africa.

We will continue the development of global land cover/use change data set based on Landsat and EOS instruments, at seasonal refresh rate. We will also begin to collect near-daily global measurements of the terrestrial biosphere from instruments on Terra. The Terra data, including derived products that represent the extent of biological activity, will help in the estimation of the role of the terrestrial biosphere in carbon exchange with the atmosphere. This information will be used to develop global and regional carbon budgets for important land cover types.

ESE will provide the first global, regional and country-by-country forest cover inventory in support of national and international needs research and sponsor two regional national assessment studies of environmental variation and natural resources vulnerability. This information can be used by land managers to manage the resources on their lands and by decision-makers in setting policies for natural resource use and/or conservation.

In FY 2001 we will continue to explore the dynamics of the global carbon cycle by developing, analyzing, and documenting multi-year data sets. Indicators of this activity will be to develop a multiyear global time series of phytoplankton biomass and primary productivity for assessing interannual variability in marine ecosystems on regional scales and daily to interannual time scales. ESE will collect near-daily global measurements of ocean chlorophyll and primary productivity using Terra and Aqua satellites, merged with SeaWifs data. Using data from Terra and Aqua we will estimate the efficiency of the carbon uptake by phytoplankton and demonstrate the value of such measurements in assessing carbon and nitrogen cycling in the open ocean. These new advances will lead us to estimating global carbon stocks and the role of land ecosystem and evaluate human impacts on land cover changes. Through use of data from the first Earth System Science Pathfinder (ESSP) mission, the VCL, ESE will be able to develop the first global sample of vegetation height and vertical structure. This information will be used to make accurate estimates of biomass in the ocean and aboveground biomass on the land that will then be used to help quantify carbon storage in their ecosystems.

ESE will continue to explain the dynamics of the global carbon cycle by building improved models and prediction capabilities. The ESE will improve, by at least 15%, the ecological models needed to predict ecosystem responses to global environmental changes through incorporation of field experiment and satellite data. Information will be provided to understand remotely sensed observations to improve efficiency of food and fiber production as well as to verify the performance of a variety of Earth system models. This will be accomplished by extending the long-term 1-4 km satellite record of global terrestrial productivity and its seasonal and interannual dynamics that was begun with the AVHRR. This activity will continue with the near-daily global measurements from instruments on the EOS Terra spacecraft, using primarily the MODIS instrument. These models will be used to predict future carbon dioxide uptake by and emission from the land and oceans as well as increases and decreases in food, fiber, and fisheries production.

Global Water and Energy Cycle: determining how water cycles among land, oceans, and atmosphere as well as impacts on fresh water availability

Ascertaining the rate of cycling of water in the Earth system, and detecting possible changes, is a first-order problem with regard to the issue of renewal of water resources. Current ESE program activities in this area are; establishing the existence (or absence) of a trend in the rate of the global water cycle, investigating the relationships between large-scale climate anomalies and weather patterns, and accurately representing the integrated effect of water vapor absorption and clouds in a way that is suitable for use in models of climate. The overarching goal is to improve the understanding of the global water cycle to the point at which useful

predictions of regional hydrologic regimes can be made. This predictive capability is essential for practical applications to water resource management and for validating scientific advances through the test of real-life prediction.

Accomplishments

In FY 1999 the Earth Science Enterprise continued to invest in observations, research, data analysis, and modeling in this area. The Tropical Rainfall Measuring Mission (TRMM), launched in 1997, completed its second year of gathering information on rainfall in the tropics where two-thirds of global precipitation falls, and about which there had been little knowledge of its distribution. This is the key to understanding Earth's hydrological cycle, one of the three major processes driving Earth's climate and the global heat balance which drives seasonal change. The data from these measurements is available through EOSDIS. Based on these measurements, the uncertainties associated with knowledge of global distribution of tropical rainfall was decreased from 50% to 25% on the way to 10% by FY 2001. TRMM precipitation data were also used to demonstrate improvements in hurricane track forecasting over the U.S. when they were incorporated into atmosphere assimilation models. This information will provide a scientific basis for quantitative precipitation forecasts in tropical regions, a principal scientific objective of global climate change research and the U.S. Weather Research Program.

The NASA Seasonal to Inter-annual Prediction Project (NSIPP) has implemented a baseline coupled climate prediction system, consisting of the Aries global atmospheric model coupled to the Poseidon global ocean model. Experimental forecasts are able to predict tropical Pacific Sea-Surface Temperatures (SSTs) up to six months in advance. The ocean model has been successfully initialized using Special Sensor Microwave/Imager (SSM/I) surface winds data, a combination of in situ and remotely measured SST's, and sub-surface temperature data from TOGA Atmosphere-Ocean (TAO) moorings. Assimilation of sea surface height data from Topex/Poseidon is now underway and will be used for the initialization of coupled forecast experiments. Future tests will include the use of QuikScat surface winds in the ocean initialization procedure. The Mosaic catchment land surface model has been developed and shown to yield improved representations of the effects of sub-grid-scale topographic variability and of soil physics in meteorological models. Knowledge of soil moisture has been shown to lend to a significant improvement in predictability of precipitation over much of the U.S. in summer. A simple three-layer snow model has been added. The snow model accounts for snow melting and refreezing, dynamic changes in snow density snow insulating properties, and other physics relevant to the growth and ablation of the snow pack. This information will provide improved seasonal predictions of changes in weather patterns associated with the El Nino cycle, and changes in land surface hydrology.

Plans

In FY 2000, efforts will focus on the development/improvement of methods to couple state-of-art land surface and sea ice models to a global coupled ocean-atmosphere model and use this to predict the regional climatic consequences of El Niño or La Niña occurrence in the tropical Pacific. The ultimate goal is to develop a capability to significantly improve the prediction of seasonal-to-interannual climate variations and their regional climate consequences. An important emphasis will be on the implications of the major interannual variations on the climate of North America. Measurements of the production and radiative properties of aerosols produced by biomass burning in Africa will be made as part of an international field experiment, the SAFARI-2000. The information obtained from this mission will assist in the interpretation of aerosol measurements made by instruments on NASA's Terra spacecraft was launched in December 1999, as well as other currently operating instruments. Biomass burning in Africa contributes a significant component of the global atmospheric aerosols. This information will provide a quantitative understanding of the impact of fires on atmospheric radiation and climate.

ESE will establish a benchmark for global and regional rainfall measurements by combining TRMM measurements with measurements from other sources. Maps of the diurnal cycle of precipitation will be created for the first time. The existing ten-year data set will be combined with TRMM measurements to validate climate models and demonstrate the impact of rainfall on short-term weather forecasting.

Complete the collection of satellite data needed for the 17-year cloud climatology being developed under the International Satellite Cloud Climatology Project (ISCCP). Data will be used to improve the understanding and modeling of the role of clouds in climate. Since the representation of clouds constitutes one of the major areas of uncertainty of climate models, the ISCCP data will be crucial to evaluating the competing ideas about how to represent cloud processes in global models.

In FY 2001 ESE will continue to explore the dynamics of the global water cycle by developing, analyzing and documenting multi-year data sets. The program will help resolve the wide disparity of precipitation estimates that currently exist, thus improving our understanding of the global water cycle. TRMM will obtain accurate maps of the diurnal cycle of precipitation and, in conjunction with a 10+ year reanalysis of SSM/I data, set a benchmark for Tropical precipitation. In preparation for a future space-based measurement of soil moisture, the airborne platforms program will demonstrate over a variety of landscapes the capability to measure and diagnose soil moisture. It is anticipated that this information will lead to reliable estimates of evaporation, precipitation, and the recycling of rainwater over continents.

ESE will also decrease the uncertainty in determinations of radiation forcing and feedback, and thereby increase accuracy in our knowledge of heating and cooling of the Earth's surface and its atmosphere. The program will continue the analysis of global measurements of the radiative properties of clouds and aerosol particles being made by the MODIS, the Multi-Angle Imaging Spectrometer (MISR), and the Clouds and Earth's Radiant Energy System (CERES) instruments on the EOS Terra satellite. ESE will continue to explain the dynamics of the global water cycle by building improved models and prediction capabilities. Improvements will be made to our current understanding of the large-scale effects of clouds in climate and the ability to model them will also improved through collection and processing of satellite data needed for the multi-decadal global cloud climatology being developed under the ISCCP. A decadal Surface Radiation Budget (SRB) climatology will be completed. These studies will serve as validation of parameterizations of Earth's radiative processes in models that simulate the cycling of fresh water through Earth's atmosphere and the transfer of visible and infrared radiation in the atmosphere. This information will provide a quantitative basis for estimating the components of the radiant energy budget of the Earth, and their impact on climate.

Climate Variability and Prediction: understanding, modeling and predicting near and long-term climate variability at global and regional scales

Climate is not perceived as a static property of the environment any more, but rather a dynamic state that is expected to evolve in the future. This research theme focuses on the modes of variability that involve in a fundamental way the dynamics of the slower components of the physical climate system, the ocean circulation and the mass balance of polar ice sheet. These components respond to disturbances with greater inertia, and therefore longer "memories", than the atmosphere. Currently ESE research seeks to~~;~~ understand the mechanisms of climate variability and predict future transient variations, assess the response of the Earth climate to changes in external forcing factors or surface boundary conditions, and assess the current mass balance of polar ice-sheets and potential future changes, including effects on sea level.

Accomplishments

The Goddard Institute for Space Studies (GISS) climate model studies have indicated the possible importance of stratospheric ozone processes for surface climate change, and thus the need for including the upper atmosphere in climate models. The climate model also reveals that increasing greenhouse gases amplify the "high" phase of the Arctic Oscillation, providing a plausible reason why Northern Hemisphere winter warming in recent years has been much larger over the continents than over the oceans. Additional model studies have been useful for quantifying and comparing the different natural and anthropogenic climate forcings that influence long-term climate change. A sophisticated ocean turbulence model has been added to the GISS climate model system. The ocean turbulence model breaks new ground in that it is the first to include salinity within a consistent theoretical framework. Also it is the first turbulence parameterization model to consistently represent vertical mixing throughout the whole ocean, from the strong mixing in the upper mixed layer to the weak mixing at depth. The models being developed thus have improved representation of physical processes and should thus provide more realistic simulation of future climate change allowing for improved climate assessment.

The Global Aerosol Climatology Project (GACP) is producing initial climatologies of aerosol optical thickness and particle size parameter using satellite measurements and transport model calculations. The initial satellite and model results are being intercompared for accuracy and precision. Analysis of field experiment measurements have been completed, data products are available from the LaRC DAAC and science results are in publication in special issues of Journal of Geophysical Research. Results of Aerosol Robotic Network (AERONET) analyses (aerosol optical thickness and size parameter) are available on the World Wide Web, for use in scientific research within 24 hours of acquisition**.** These data are incorporated in climate and atmospheric chemistry models to improve their ability to simulate environmental change in response to change in aerosol loading.

Significant progress was made in studies of ice-covered regions of the Earth. A larger, statistically significant decrease in the amount of sea ice in the Northern Hemisphere over the past 20 years has been documented. Changes in the height of ice in Greenland over a several year period have been demonstrated using airborne measurements. A high-resolution model of the structure of ice in Antarctica has been created using data from the Canadian RADARSAT mission. These data show the existence of “ice streams” that transport ice more rapidly than previously expected. This motion has the potential to lead to more rapid reduction of ice amounts in a warming environment than had been previously assumed potentially accelerating the rate of sea level rise.

The QuikScat spacecraft, launched in FY 1999, joins TRMM and the Ocean Topography Experiment/Poseidon (TOPEX/Poseidon), to form a powerful suite of space-based observational asset to track phenomena such as El Niño/La Nina. QuikScat replaced the NASA Scatterometer instrument that was lost in the failure of Japan's ADEOS spacecraft launched in 1997. With QuikScat ESE began measurement of sea-surface wind speed and direction at a spatial resolution of 25km resolution over at least 93 percent of the ice-free global oceans every two days. This represents a resolution increase of a factor of two, and a 15 percent increase in coverage over previous measurements. Data from this mission will be used to improve the short-term weather forecasts.

Plans

There is increasing evidence that predictions of extreme weather events can be improved by understanding their links to interannual climate phenomena like the El Niño events. In FY 2000, through the Terra instruments, we will begin conducting daily

observations of cloud properties such as extent, height, optical thickness, and particle size. We will map aerosol formation, distribution properties and sinks over the land and oceans. In addition, we will achieve a substantial reduction in the uncertainty in components of the Earth's radiation balance (e.g. improved angular models leading to an estimated error reduction in regional-scale monthly-average net radiation of about 50%). Besides improving our basic understanding of the distribution of these parameter fields the resulting data will be used in evaluation of climate change models.

Efforts in FY 2000 include analysis of the CERES measurements to achieve a further reduction in the uncertainty in the determination of top-of-the-atmosphere radiative fluxes through the integration of measurements provided by the CERES instruments on TRMM and Terra. The data provide a critical test of the radiative aspects of climate change models.

The first detailed estimates of thickening/thinning rates for all the major ice-drainage basins of the Greenland ice sheet, derived from repeated airborne laser-altimetry surveys will be published. These measurements also represent a baseline data set for comparison with early measurements to be made by ICESat, to be launched in 2001. The airborne project for mapping of layers within the Greenland ice sheet to decipher the impact of past climate variation on polar regions will be initiated. Through a RADARSAT repeat of the Antarctic Mapping Mission a second set of high-resolution radar data will facilitate a comparison of baseline data to identify changes on the ice sheet. The data obtained will help assess possible ice sheet changes so that their effect on sea level change can be examined.

The launch of the NASA-CNES Jason-1 mission in FY 2000 will enable a factor-of-four improvement in accuracy in measuring ocean basin-scale sea-level variability versus TOPEX/Poseidon. Additionally ESE will generate the first basin-scale high-resolution estimate of the state of the Pacific Ocean as part of the international Global Ocean Data Assimilation Experiment (GODAE). This information will serve as input for seasonal weather forecasting models and should lead to improved representation of the physical coupling between the oceans and the atmosphere in climate models.

With the launch of EOS ACRIMSAT, continual long-term, continuity in measuring the total solar irradiance will be assured. It will provide a total solar irradiance data set for the complete period of maximum solar activity (2000 – 2005). The absolute accuracy of this data set will be equal to or better than previous space-based measurements, about 1000 ppm, and will provide a quantitative understanding of the solar forcing of Earth’s climate. This information will be used as input to climate change models so that the effect of the variability in this natural external forcing of the climate can be simulated.

ESE will continue the development of the global aerosol climatology data set and analysis of this climatology in climate models. Data will be available in the GSFC DAAC. This effort will help continue to improve the design and sophistication of a global climate system model that will contribute to the First National Assessment of the Potential Consequences of Climate Variability and Change. This information will bring a new perspective to our understanding of the processes driving our climate.

In FY 2001 ESE will continue to explore the dynamics of long-term climate variability by developing, analyzing, and documenting multi-year data sets. In FY 2001, ESE will complete detailed mapping of thinning/thickening rates for all major ice catchments on the Greenland Ice Sheet from airborne laser altimeter data. This will serve as a baseline for future satellite-based surveys, to determine the behavior of the ice sheet and its influence on global sea level change. Continue the measurement of ocean basin-scale sea-level variability with Jason-1 satellite data. ESE will also continue, through ACRIMSAT the high precision, multi-decadal record of total solar irradiance measurements towards capturing three solar cycles. This information will provide a quantitative basis for assessing the contribution of solar variability to on-going climate change.

ESE will continue to explain the dynamics of long-term climate variability by building improved models and prediction capabilities. Observational capability will be enhanced through development and demonstration of a technique to measure and diagnose open ocean variations in salinity by 0.1 psu from airborne platforms. Salinity is a critical factor in forcing ocean circulation. Work will be done to improve understanding and modeling of the aerosol radiative forcing of climate and its anthropogenic component as needed for the 20-year climatology of aerosol optical thickness and particle size under the GACP. This will be accomplished through the development and validation of aerosol retrieval, cloud-screening algorithms, processing of satellite data and transport model evaluations. We will demonstrate the experimental seasonal climate predictions by using next-generation super computing systems and new-coupled air-ocean-land-ice models. This demonstration will incorporate all available satellite observations (e.g., TOPEX, Jason, Seawinds, TRMM, SeaWifs, MODIS) of key ocean surface parameters such as wind vectors and altimetry. The accuracy of realistically forced long-term climate models will be enhanced to simulate observed global temperature research. Particular emphasis will be placed on the seasonal and spatial variability over the last 40 years to develop improved confidence in ability of models used for climate prediction. This information will provide the scientific basis for reliable assessments of potential future changes in global and regional climates.

Atmospheric Chemistry: monitoring and predicting how atmospheric composition is changing in response to natural and human-induced factors

Atmospheric change is the result of strongly interactive chemical and physical processes. Chemistry plays a role in determining weather and climate, while the physics and dynamics of the atmosphere influence chemical processes and composition. The goals of the atmospheric Chemistry research program are to measure and understand how atmospheric composition is changing in response to natural and anthropogenic forcings, and enable accurate prediction of future changes in ozone and surface ultraviolet radiation, climate forcing factors, and global pollution.

Accomplishments

Fulfilling its Congressional mandate for upper atmosphere and ozone research, ESE has acquired a twenty-year data set on ozone concentration and distribution. ESE continues to explore the chemical processes of ozone destruction and replenishment in the stratosphere, and is beginning to probe the complex chemistry of the troposphere, the lower portion of the atmosphere in which we live. ESE employs this capability to make essential contributions to international scientific assessments of ozone by the World Meteorological Organization. NASA's contributions in this area are to develop and operate space-, airborne-, and ground-based instruments that will map the fluctuations in ozone, aerosols and related constituent gases in the atmosphere, as well as develop models that can be used to simulate prior and future evolution of atmospheric composition. These models will provide added insight into changes in the atmosphere and potentially its influence on climate.

In FY 1999 NASA has utilized an integrated program of space, aircraft, balloon, ground-based and laboratory measurements, along with global and process scale modeling activities to achieve a number of significant accomplishments toward understanding the causes of variation in ozone concentrations and distribution in the upper and lower atmosphere. This information will provide improved knowledge of chemical and aerosol processes incorporated in assessment models.

In FY 1999 ground-based, balloon-based, and airborne in situ and remote-sensing measurements continued to show evidence that the halogen burden in the lower atmosphere is beginning to decline in response to actions taken in response to the Montreal Protocol. Global measurements from the Upper Atmosphere Research Satellite (UARS) have yielded the first evidence of this response in the upper stratosphere. This information demonstrates consistency in our knowledge of the chlorine chemistry of the stratosphere and helps lend further credence to the models used to assess future atmospheric chemical change.

The Total Ozone Mapping Spectrometer (TOMS) continues to provide the global view of how ozone is responding to these reductions in atmospheric halogen burden, and is providing new data products such as tropospheric ozone columns. The Southern Hemisphere Additional Ozonesonde network (SHADOZ) and the field measurements phase of the Pacific Exploratory Mission (PEM-Tropics-B) provided additional advances in tropospheric chemistry. Satellite data from the second Stratospheric Aerosol and Gas Experiment (SAGE II) and lidar data have shown that the distribution of stratospheric aerosol amounts are as low or lower than they have been since accurate global measurements began. In response to the launch delays for the SAGE III instrument due to problems experienced by our Russian partner, the ESE supported the continued operation and data processing for the DOD Polar Ozone and Aerosol Mission (POAM) satellite instrument, thereby providing high latitude data on distribution of ozone, aerosols, water vapor, and nitrogen dioxide. The SAGE and POAM data will help improve our knowledge of stratospheric aerosols under these new background conditions and their contribution to atmospheric chemical change.

Three new data products were produced from TOMS data including surface ultraviolet (UV), tropospheric ozone column amounts and UV absorbing tropospheric aerosols. Progress was made on understanding Solar backscatter Ultraviolet (SBUV2) characteristics. Improvements to the calibration correction, the nonlinearity corrections for the Photomultiplier Tube and understanding the instrument's orbital hysteresis are complete, and reanalysis is taking place. Re-analysis was applied to the intercalibration and gap filling of the TOMS data. This re-analysis has revealed seasonal features that require further investigation prior to final release of the new 20-year ozone data set. This data set represents one of the primary long term records of Earth system change and is used in the evaluation of atmospheric chemistry models as well as input to climate change models.

The detailed multi-aircraft study of troposphere chemistry over the tropical Pacific Ocean continued, including the contribution of long-range transport of air from South America and Africa to otherwise unpolluted areas. The field measurements phase of PEM-Tropics-B (rainy season) was completed with an improved payload that has resulted from an initiative to develop a smaller, lighter payload with equal or better performance than PEM-Tropics A (dry season). The results were released in October 1999. The results will improve our knowledge of the factors that govern the chemical composition (pollutant levels of areas of the atmosphere previously thought to be little subject to human influence).

Surface levels of chlorine- and bromine-containing chemical compounds addressed under the Montreal Protocol were measured. This documents the decreasing concentrations of the regulated compounds and the rising concentrations of their replacements to quantify the decrease in total halogen abundance in the lower atmosphere. The analyses were incorporated in the United Nations Environment Program/World Meteorological Organization (UNEP/WMO) "Assessment of Ozone Depletion 1998" Monitoring Project Report #44, that was completed in FY 1999. These data help test international compliance with the Montreal Protocol and support the further evaluation of the assessment models used in the study of ozone depletion.

Plans

Efforts in FY 2000 will implement the SAGE III Ozone Loss and Validation Experiment (SOLVE). Measurements will be made during the timeframe of October 1999 - March 2000 in the Arctic and high-latitude region in winter using the NASA DC-8 and ER-2 aircraft, as well as balloon platforms. The mission will also acquire correlative data needed to validate the SAGE III satellite measurements that will be used to quantitatively assess high-latitude ozone loss. In FY 2001 comprehensive analysis of the data will provide increased prognostic ability for Northern Hemisphere high latitude ozone loss in an atmosphere perturbed by an increased abundance of greenhouse gases. The improved models that will be developed in response to these data will be used in assessments of future ozone changes and their impact on climate.

The initial analysis and publication of the PEM-Tropics-B field experiment will be complete by the end of FY 2000. This information will provide improved knowledge of the processes by which trace gases and aerosols can be transported over long distances from source regions to otherwise less polluted regions of the atmosphere.

The ESE will continue to monitor and assess the impact of the Montreal Protocol and the Framework Convention on Climate Change with globally distributed measurements of the surface level concentrations of long-lived industrially produced trace gases and other biogenically-produced gases such as methane and nitrous oxide. In addition, we will complete acquisition of first ever-global climatology of vertical profiles of carbon monoxide (CO) to improve knowledge of its surface sources, photochemical destruction, and how it is transported by tropospheric wind systems (based on MOPITT data from Terra). This will lead in 2001 to improved assessment of the role of the global budget of carbon monoxide and methane (including its role in the global carbon cycle) through the development of the first global climatology of carbon monoxide and total column methane. Detailed validation of the MOPITT data product will be carried out with a variety of surface- and airborne-based in situ sampling, as well as ground-based optical remote sensing instruments. The data will improve our understanding of the contribution of fires and fossil fuel combustion to global pollution and to better assess our knowledge of the sources of methane and thus its potential contribution to atmospheric and chemical climate change.

In FY 2001 ESE will provide continuity of multi-decadal total ozone concentration measurements using the existing Earth Probe TOMS satellite instrument and its successor the QuikToms spacecraft, planned for launch late FY 2000, and related space and

ground based total ozone measurements. This will aid in characterization of long-term evolution of ozone and enable assessment of ozone recovery processes, and in assessment of the adequacy of current international regulations to protect the ozone layer in a changing climate.

We will continue to monitor atmospheric concentrations of chlorofluorocarbons (CFCs) and new industrial substitutes through implementation of gas chromatographic mass spectrometric instrumentation within the Advanced Global Atmospheric Gases Experiment (AGAGE) in-situ network. This will be done to assess international compliance with the Montreal Protocol and provide a firm basis on which to assess their contribution to ozone depletion and climate change. A comprehensive climatology of high-resolution ozone vertical distribution in the southern subtropics will be developed (upper troposphere and lower stratosphere). The climatology will be based on a complete first year of data from SHADOZ network. Tropospheric ozone values obtained from TOMS data will be compared with integrated tropospheric ozone values from SHADOZ to assess the accuracy of the TOMS tropospheric ozone algorithms. We will characterize long-term (multi-decade) evolution and interannual variability in high latitude ozone, aerosol, and polar stratospheric cloud profiles through combination of SAGE III data with those from previous instruments such as SAM, SAM II, SAGE, SAGE II, and POAM. These data will improve our knowledge of the role which ozone changes may play in contributing to climate change as well as the way in which ozone concentrations may respond to climate variation.

The time evolution of ozone and aerosol fields over the sunlit Earth will be directly measured for the first time in FY 2001 using observations from the Earth Polychromatic Imaging Camera (EPIC) instrument on the Triana spacecraft. These Triana observations will also allow the first daily diurnally integrated estimates of surface UV radiation based on satellite data of overlying ozone, aerosol, and cloud distributions, which will be provided to scientists interested in ecological and health effects of surface UV radiation.

ESE will continue to explain the dynamics of atmospheric composition by building improved models and prediction capabilities. In FY 2001 stratospheric model development will be focussed on increased prognostic ability for Northern hemisphere high latitude ozone loss in an atmosphere perturbed by and increased abundance of greenhouse gases through comprehensive analysis of data from the SOLVE coordinated field experiment. Also, ESE will provide improved assessment of the role of the global budget of carbon monoxide and methane (including its role in the global carbon cycle) through the development of the first global climatology of carbon monoxide and total column methane using data from the MOPITT instrument aboard the EOS-Terra satellite. In addition, work will be done to characterize atmospheric plume flowing out of East Asia, its evolution as it transits eastward over the Pacific Ocean, and its contribution to global atmospheric chemical composition. In FY 2001, a major multi-aircraft campaign known as the Transport and Chemistry near the Equator over the Pacific (TRACE-P) is planned for East Asia to help assess the effects of outflow of trace gases and particulates into the Western Pacific Ocean. This mission will be planned to incorporate the use and analysis of satellite data and atmospheric models, and improve our understanding of the way in which changes in global atmospheric chemistry affect and are effected by changes in regional air quality.

Solid Earth and Natural Hazards (Solid Earth portion): discovering the nature and processes of the Earth's dynamic interior and crust to better prepare for natural hazards.

The resources for this theme area are shared between Earth Science Program Science (Solid Earth) and the Applications, Commercialization and Education program (Natural Hazards). Since the Solid Earth activity is more Science related it is managed more appropriately with ESE's other basic Science Research activities. The Natural Hazards theme area is better served as part of

the Applications Research program due to its relevance to the ACE initiatives focussed on bringing scientific results to a more immediate practical use.

The long-standing Earth science research program in fundamental solid Earth science explores issues such as the dynamics of the Earth's interior and crust, tectonic motions, earthquakes, volcanic eruptions, and the evolution of landscapes. Results of this and other relevant activities are developed and applied to the assessment and mitigation of natural disasters for the practice of disaster management, working together with practitioners at the international, federal, state and local levels. Through the development of technologies designed to observe and understand the Earth, the ESE possesses an inventory of observational capabilities and techniques which can be developed and applied to understanding natural hazards, characterizing natural disasters, and monitoring conditions that may lead to such events.

Accomplishments

In FY 1999, the Shuttle Radar Topography Mission (SRTM) instrument was developed to create a near-global high-resolution digital elevation topographic map of the world. The instrument was integrated on the Endeavor and is scheduled for launch in early 2000. The data from the SRTM will allow scientists in federal, state and local agencies, and academia to study the terrain for basic research such as ecology, geology, geodynamics, hydrology and atmosphere modeling. This information provides a multi-disciplinary tool for assessing vulnerability to natural hazards and sensitivity to local environmental changes.

During 1999, the Global Positioning System (GPS) array in Southern California monitored crustal deformation, recording and transmitting on a daily basis. Data and solutions for site velocities and time series of site positions were made available on the internet. These measurements clearly identified discontinuities in the direction and magnitude of crustal motion across fault lines. Federal, state and local agencies and companies are using the Southern California Integrated GPS Network (SCIGN) data to study ground deformation related to earthquakes, and to continually assess the vulnerability and risk of earthquakes to the region. Local agencies and surveying groups are also using SCIGN data for their spatial reference system and beginning to support the operations of the array. This information will provide a scientific basis for understanding the earthquake cycle and laying out the foundation for earthquake prediction.

The coupling of the dynamics of the solid earth to that of the atmosphere was demonstrated with the use of data from the very Long Baseline Interferometry (VLBI) network. In particular, variations in the length of daylight were highly correlated with the dynamics of the ocean-atmosphere system associated with the El Nino Southern Oscillation.

As part of the effort to test improved algorithms for sounding the atmosphere with occulted GPS signals, the Oersted spacecraft is successfully obtaining precision GPS data and occultations for six out of every 27 hours. The JPL project team is analyzing this data, and the results will be published in science literature. This information will provide the basis for assessing the effectiveness of this new observing technique for climate change studies and weather prediction.

Plans

In FY 2000, we will continue to use the Southern California GPS (SCGPS) array data to develop an understanding of the connection between seismic risk and crustal strain leading to earthquakes. This will be done by monitoring the movement of the ground over

time to detect strain buildup or subsidence, and installing another 100 of the SCGPS array of precision GPS locators/receivers for monitoring strain accumulation.

Research in FY 2000 will continue to develop models to use static and time-varying gravity observations (in conjunction with the Challenging Mini-satellite Payload (CHAMP) and GRACE Missions) to better understand variations in the Earth's gravity field estimate water storage changes to provide data to hydrologists on water mass expansion and climate variations. In addition, we will continue observational efforts using Satellite Laser Ranging and Global GPS to maintain the International Terrestrial Reference System as a reference for other geodetic observations that include gravity variations, sea level observations, ground deformation observations and other geodetic observations of the earth. This information will maintain and improve the determination of the global geodetic reference frame for satellite navigation systems and GPS-based observations.

The SRTM instrument will be launched in early FY-2000, and will gather topographic data. During FY 2000 and through FY 2001, we will conduct analyses of the near-global SRTM 30 meter topographic data for global geologic and geomorphic process studies. This will provide the first continuous digital elevation model of 80% of the Earth's surface for better understanding the composition and processes on the Earth's surface for scientific understanding and urban and aircraft flight planning purposes.

In FY 2001 ESE will continue to explore the dynamics of the Earth's interior and crust by developing, analyzing, and documenting multi-year data sets. We will use the daily orbit solutions for all GPS constellation satellites as a basis for cm-level orbit determinations and mm-level ground-based GPS positioning and navigation. This will enable near-real-time assessment of ground deformation for disaster response after earthquakes, and swelling of the ground as a precursor to explosive volcanic eruptions.

ESE will continue to explain the dynamics of the Earth's interior and crust by building improved models and prediction capabilities. This will be accomplished by improving our understanding of geodynamic processes through the completion of the VLBI Mark IV Correlator upgrade which will result in increased observation frequency, faster data processing and lower operational costs. ESE will also complete the second phase of SCIGN array of 250 precision GPS locators/receivers installation. This information will improve our ability to monitor crustal movements.

EOS Science

In 1988, NASA issued an Announcement of Opportunity (AO) for the selection of instruments, science teams and interdisciplinary investigations in support of the Earth Observing System (EOS). The initial EOS/IDS investigations were selected in 1990 to conduct basic research, develop methods and models for analysis of EOS observations, develop and refine models of Earth system processes, and forge new alliances among scientific disciplines fostering a new perspective into how the Earth functions as an integrated system. These investigations involved analysis of data from EOS precursor missions (e.g. TRMM, Landsat-7) and international instruments (e.g. ADEOS, ERS, Radarsat) and in situ observations, with results being made available through EOSDIS to enhance broad participation by the science community at large. Subsequently, additional IDS investigations were selected bringing the total to 71.

Plans

In FY2000 the first round of EOS interdisciplinary science investigations will be essentially completed. These consist of the historical interdisciplinary investigations (10-year grants), the subsequent interdisciplinary investigations (3-year grants), and the investigations associated with the Joint Global Flux Program (JGOFS), (also 3 year grants). The entire interdisciplinary science investigations program was re-competed in FY1999 through the AO process, with new selections planned for early FY2000 and FY2001. This series of investigations will capitalize on exploitation of the data to be provided by Landsat 7 and QuikScat as well as the Terra (EOS AM) spacecraft, launched in December 1999, and the Aqua (EOS PM) spacecraft scheduled for launch in 2000.

Mission Science Teams and Guest Investigators

The mission science team/guest investigators program provide the opportunity for scientists from all institutions to participate in the analysis, verification, and utilization of data from NASA's currently operating space-based instruments. Funding provides for analyzing data from the UARS, TOPEX, Earth Radiation Budget Satellite (ERBS) and other space borne instruments such as Solar Backscatter Ultraviolet (SBUV/2), TOMS, QuikScat, and TRMM. The exploitation of UARS data still involves more than 100 investigators from the United States and many other countries, notably Canada, the United Kingdom, and France. Key TOMS and SBUV/2 participants include NOAA, Russia, and Japan. Key ERBS users include a diverse set of institutions including NOAA (NOAA manifested Earth Radiation Budget Experiment (ERBE) sensors on NOAA-9 and -10 in the 1980's), GSFC, LaRC, the State University of New York, Oregon State University, and the Scripps Institution of Oceanography. The TOPEX users include France (shared in development of the mission), Japan, Australia, the United Kingdom, the Netherlands, Germany, Norway, and South Africa as well as JPL, GSFC, Columbia University, the University of Hawaii, the University of Texas, the University of Colorado, Oregon State University, Ohio State University, and the Massachusetts Institute of Technology. SeaStar/SeaWifs principal users include GSFC, the European community, Japan, Canada, and Australia and universities in Florida, Washington, California, Texas, Maryland, and Rhode Island. At present, the largest demand for ocean color data arises from the Joint Global Ocean Flux Study (JGOFS), an international program under the auspices of the Scientific Committee for Oceanographic Research (SCOR) and the International Geosphere-Biosphere Program (IGBP). Active international participation through the International Ocean Color Coordinating Group is carried out to help synthesize data from the various space-based ocean color sensors of different nations that are currently operating. NSCAT investigators include scientists from JPL, NOAA, and Japan (manifested the NSCAT for flight on their ADEOS-1 spacecraft), and universities in New York, Washington, Oregon, and Florida. TRMM is a joint mission with Japan to measure tropical precipitation from a low inclination orbit. Participants in the analysis of Shuttle Imaging Radar/X-Band Synthetic

Aperture Radar (SIR-C/X-SAR) data, in addition to JPL, represent nations in almost every continent including Italy, Saudi Arabia, China, Australia, France, Canada, Brazil, the United Kingdom, and Germany.

In a number of cases, data from one instrument have been shown to have use in other applications, and the mission analysis programs actively encourage such uses. Mission science teams are typically competed triennially. The budget for these teams is expected to begin to increase significantly in FY 2001, as funds that were provided to the EOS instrument science teams for algorithm development will be converted to mission analysis following the launch of the relevant missions and spacecraft.

Airborne Science and Applications

In FY 1999, twelve major campaigns were flown, over 1470 flight hours. The campaigns produced science data for rainfall, land-cover/land-use and atmospheric chemistry. Six major campaigns are scheduled for FY 2000, over 1400 flight hours. The core NASA Earth science aircraft fleet is fully subscribed, therefore lease, or other acquisition method, will again be used to fulfill the requirements which cannot be met by the core fleet. The campaigns will return scientific data on arctic ice and meltponds, atmospheric chemistry, land-cover/land-use, and salinity.

Uncrewed Aerial Vehicles (UAVs)

The UAV science project will augment the Earth science airborne project. Initially it will make i*n situ* and remote-sensing measurements focused on atmospheric sciences. These UAVs will stay over a target for extended periods to measure detailed temporal changes, provide unique views of cloud structures and provide calibration and verification of Earth science satellite instrumentation. Initial work in the UAV science was to develop and test a payload of instruments suitable for study of the radiation field in the upper troposphere and lower stratosphere as well as the relationship between atmospheric physical and chemical parameters and the radiation field. The centerpiece of this payload is a newly constructed high-resolution infrared and far infrared radiometer. The radiometer has been tested on the ER-2 and has been flown on the ER-2 together with several other instruments making measurements of atmospheric physical and chemical properties in order to provide enough data to test the retrieval algorithms used to interpret data from the radiometer. Both series of test flights were carried out from the Dryden Flight Research Center in California.

Accomplishments

In FY 1999, a stratospheric chemistry instrument suitable for flight on a UAV (small, lightweight and autonomous) was developed and is being flown to verify its performance in the SOLVE mission. Assistance was given to the flight demonstration program to increase UAV heritage to improve user confidence in the UAV as a viable platform

Plans

In FY 2000, the plan is to fly the radiometer and a small number of other instruments on a UAV. The UAV must have sufficient flight heritage and instrument modifications will be necessary to mate with the selected UAV. For FY 2000 and beyond, a NRA will be issued soliciting UAV missions supporting the science and applications goals of the ESE. The NRA will solicit 2-3 UAV-based Science Demonstration missions in the PI-mode. In FY 2001, the UAV-based Science Demonstration Program will be underway with 2-3 missions preparing payloads for flight. These missions which to be selected should make use of the unique capabilities of UAVs and help improve our knowledge of one or more of the components of the Earth system.

Information Systems

The Earth science information systems project will continue to provide a balanced computational environment for NASA science researchers primarily through the facilities housed at GSFC and JPL. Partnerships with industry and other federal agencies will be used to assure the presence of the project's requirements in the strategic planning of new computational technologies. Recently initiated cooperative agreements will allow the development of supercomputer applications 10 times faster than today, providing the computational studies necessary to mesh with NASA's observational and theoretical projects.

BASIS OF FY 2001 FUNDING REQUIREMENT

RESEARCH AND TECHNOLOGY

PROPOSED NEW STRUCTURE

APPLICATIONS, COMMERCIALIZATION, AND EDUCATION

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Research and Analysis – Applications	[25,600]	[32,769]	21,200
Commercial Remote Sensing	[38,100]	[30,435]	31,900
Education	[11,900]	[15,200]	16,100
EOS Fellowships and New Investigators	[4,800]	[5,300]	7,000
Education and outreach	[2,100]	[4,900]	4,100
Global Observations to Benefit the Environment	[5,000]	[5,000]	5,000
Subtotal Without Education Agency Investment	[75,600]	[78,404]	69,200
Education Agency Investment	[7,300]	[7,300]	--
Total	[82,900]	[85,704]	69,200

Note: Earth Science Program Science in FY01 has been broken out to reflect the distinction between the Research Program and the Applications, Commercialization and Education (ACE) Program. These changes are reflected in realignment of the following areas to the ACE program: applications portion of R&A, the fellowships portion of EOS Science, and the Commercial Remote Sensing Program.

PROGRAM GOALS

The goal for the Applications, Commercialization and Education program is to Expand and accelerate the realization of economic and societal benefits from Earth science, information and technology. This is to be done by enabling productive use of Earth system science results, data and technology in the public and private sectors, supporting the development of a robust commercial remote sensing industry, and increasing public understanding of and involvement in Earth system science through formal and informal educational opportunities.

STRATEGY FOR ACHIEVING GOALS

The applications Research and Analysis (R&A) effort is essential to the discovery of new concepts and to the design of future missions. The primary mode of research coordination occurs through the USGCRP, the Committee on the Environment and Natural Resources (CENR) Subcommittee on Global Change Research, and the various boards and committees at the National Academies of Sciences. The applications R&A consists of one of the five management areas: the Natural Hazards portion of Solid Earth and Natural hazards.

The Science strategy of interdisciplinary research is to increase scientific understanding of the global environment and its vulnerability to both human and natural factors of change (e.g. pollution, climate variability, deforestation). Natural hazards research is exploring the use of science, technology, and remote sensing observations for the assessment of vulnerability to natural hazards and mitigation of natural hazards including earthquakes, volcanic eruptions, landslides, drought and flood consequences.

The Commercial Remote Sensing Program (CRSP) funds cooperative efforts with industrial, university, and state and local government partners aimed at enabling development of a viable commercial remote sensing industry. The cooperative effort will work to apply space-based data and instrument technology in the demonstration of usable, customer-defined information products. Industry and others will make significant co-investments, funding or in-kind contributions to the co-developed projects at about an equal level with NASA.

The Education program seeks to increase public understanding of and involvement in Earth system science through formal and informal educational opportunities. This activity ranges from graduate student participation in the Earth System Science Fellowship (ESSF) program and new faculty member participation through the New Investigator Program (NIP) to participation in the Global Observations to Benefit the Environment (GLOBE) program. The goal of the GLOBE program is to link scientific discovery with the education process in the study of the Earth as an integrated system. The objective is to bring school children, teachers, and scientists together to: (1) enhance environmental awareness of individuals throughout the world; (2) contribute to scientific understanding of the Earth; and (3) help all students reach higher levels of achievement in science and mathematics.

The GLOBE program is an interagency activity led by NOAA in which NASA has a key role. It involves students (kindergarten through twelfth grade or equivalent) in schools throughout the world, their teachers and the research community. Participating schools are making core sets of GLOBE measurements using GLOBE instruments and procedures under the guidance of GLOBE-trained teachers. The results from all over the world are reported into a central data processing facility. The students then receive feedback and use GLOBE educational materials to understand the compiled results and do their own analyses of the data. The program is designed to be international in scope, involving students, educators and researchers from all over the world. By using the Internet to link the schools together, a sharing of discoveries and analysis is encouraged that should result in awareness beyond

just the local community. This program also seeks to contribute to the scientific understanding of the Earth. International environmental scientists have been involved from the beginning of the program to select a set of significant scientific measurements that can be made by students and define the experimental procedures and data reporting protocols for each.

SCHEDULE AND OUTPUTS

The scientific issues of concern to Earth science are among the most complex and policy relevant of any major scientific research program. The results of Earth science program science are critical to the development of sound U. S. and global environmental policy, necessary for long-term sustainable development. Each of the science theme areas discussed in the accomplishments and plans section describe performance targets to ensure that the goal and objectives of the Earth science program science are met. A summary schedule and outputs relating to management, business practices, and bases for comparisons applicable to the whole Earth science program are in the table below.

Natural hazards only	FY 1999 Actual	FY 2000 Estimate	FY 2001 Estimate
Number of principal investigators	15	15	15
Number of research tasks under way	16	16	20
Average duration of research tasks	3 years	3 years	3 years
Number of science solicitations released	.5	.5	1
Number proposals received	53	60	70
Number of proposals rated very good to excellent	17	20	20
Number of proposals selected	14	15	15
Time to process proposal (selection through obligation)	45 days	30 days	30 days
Number of days until funding is released	Simultaneously with award	Same	Same
Percent of R & A funding obligated:			
Current Budget Authority:	87%/91%	100%	100%
Prior Budget Authority:	100%	100%	100%
Percent of program reviewed by science peers	95%	95%	95%

* Estimate revised due to consolidation of solicitations.

SCHEDULE AND OUTPUTS FOR GLOBE

	FY 1999		FY 2000		FY 2001
	Plan	Actual	Plan	Revised	Plan
Number of Participating Schools	8,000	7,767	10,500	10,300	10,500
Number of Participating Teachers (Revised goal for FY 2000 and beyond)		11,300	12,000		13,800

ACCOMPLISHMENTS AND PROPOSED RESULTS

RESEARCH AND ANALYSIS – Applications

In FY 1999, continuing into FY 2000 and FY 2001, the following are significant accomplishments in the area of Natural Hazards and applications research.

Solid Earth and Natural Hazards (Natural Hazards portion): discovering the nature and processes of the Earth's dynamic interior and crust to better prepare for natural hazards

The long-standing Earth science research program in fundamental solid Earth science explores issues such as the dynamics of the Earth's interior and crust, tectonic motions, earthquakes, volcanic eruptions, and the evolution of landscapes. Results of this and other relevant activities are developed and applied to the assessment and mitigation of natural disasters for the practice of disaster management, working together with practitioners at the international, federal, state and local levels. Through the development of technologies designed to observe and understand the Earth, the ESE possesses an inventory of observational capabilities and techniques which can be developed and applied to understanding natural hazards, characterizing natural disasters, and monitoring conditions that may lead to such events.

Accomplishments

In FY 1999, the Shuttle Radar Topography Mission (SRTM) instrument was developed. This instrument will enable the creation of a near-global high-resolution digital elevation topographic map of the world. The instrument was integrated on the Endeavor and is scheduled for launch in early 2000. The information from this mission will be used to produce one of the most comprehensive and accurate maps of the Earth ever assembled, offering a number of applications for data products and science including: geology, ecology, geology, geodynamics, hydrology, volcano monitoring, flood inundation modeling and atmosphere modeling, as well as applications in urban and infrastructure planning, and disaster management.

During 1999, the Global Positioning System (GPS) array in Southern California monitored crustal deformation, recording and transmitting on a daily basis. Data and solutions for site velocities and time series of site positions were made available on the internet. These measurements clearly identified discontinuities in the direction and magnitude of crustal motion across fault lines. Federal, state and local agencies and companies are using the Southern California Integrated GPS Network (SCIGN) data to study ground deformation related to earthquakes, and to continually assess the vulnerability and risk of earthquakes to the region. Local agencies and surveying groups are also using SCIGN data for their spatial reference system and beginning to support the operations of the array.

Plans

In FY 2000, we will continue to use the Southern California GPS (SCGPS) array data to monitor the movement of the ground over time to detect strain buildup or subsidence, and installing another 100 of the SCGPS array of precision GPS locators/receivers for monitoring strain accumulation. This information will help to develop an understanding of the connection between seismic risk and crustal strain leading to earthquakes.

Natural hazards research in FY 2000 will continue to study flooding and floodplain processes, process and distribute imagery of current flooding for broad use in flood damage assessment and assessment of accuracy of flood plain maps comparing current flood insurance maps. In this regard, we have partnered with the Federal Emergency Management Administration (FEMA) to evaluate and demonstrate the utility of remote sensing data for improved, faster and less costly flood plain mapping.

The SRTM instrument will be launched in early FY 2000, and will gather topographic data. During FY 2000 and through FY 2001, we will conduct analyses of the near-global SRTM 30 meter topographic data for global geologic and geomorphic process studies, comparative analysis, improved mapping of terrain features such as floodplains, and input to models for improvement of assessment of natural hazards. This will help in understanding the risk of natural disasters in developed areas and areas proposed for development to help better assess the risk of floods in developed areas and areas proposed for development.

In FY 2000, ESE will develop an automatic volcano eruption detection procedure using EOS Terra data sets that will automatically detect eruptions and monitor and track plumes. These procedures will be infused into ongoing efforts with the Federal Aviation Administration (FAA) for use in aircraft routing and warning systems. This information will help promote safe air travel.

ESE will continue to explain the dynamics of the Earth's interior and crust by building improved models and prediction capabilities. This will be accomplished by improving our understanding of geodynamic processes through the completion of the VLBI Mark IV Correlator upgrade which will result in increased observation frequency, faster data processing and lower operational costs. ESE will also complete the second phase of SCIGN array of 250 precision GPS locators/receivers installation. This information will help to better assess the vulnerability and risk of earthquakes.

RESEARCH AND ANLAYSIS -- APPLICATIONS

The goal of the Earth Science Applications Research Program (ESARP) is to demonstrate the productive use of ESE science and technology in the public and private sectors in response to user needs. To achieve the goal, the ESARP works with non-NASA public and private partners to demonstrate Earth Science results, data and technology to a broad range of users for near-term practical applications.

The elements of ESARP that contribute to this goal are as follows:
1. Regional Earth Science Application Centers (RESACs): Help state and local government agencies and private industry understand the potential impact of climate change on agriculture, forest growth and health, wildfire hazard and watershed and coastal management. This information will help government agencies and commercial enterprises make informed land use decisions.

2. Joint projects with the Department of Agriculture: NASA is assisting DOA develop new approaches to the use of remote sensing in agriculture. The benefit of this program will be, among other things, more efficient and less polluting agriculture. For example, NASA is working with grape growers in California developing ways they can use high resolution remote sensing data to identify grapes ready for harvest, and radar data to gauge soil moisture and improve irrigation efficiency both procedures will have direct impact on vineyard efficiency and profit.

3. Earth Science Information Partnerships (ESIPs): The ESIPs are focused on using data from NASA's Earth Observation System in innovative ways, from improving the accuracy and timeliness of weather reports to emergency services. These partnerships will, among other things, understand weather phenomena and how those phenomena affect them, and assist agencies responsible for emergency services distribute better information faster to representatives in the field and to the public.

4. State and local programs: ESARP is working directly with state and local governments to help them realize the potential information content of NASA data. These projects will help state and local agencies acquire information at lower cost and with greater accuracy than ever before. The projects will also help state and local agencies make data and information available to the public faster and at lower cost.

Accomplishments

In FY 1999, ESARP initiated seven integrated Regional Earth science Applications Centers (RESACs) designed to apply remote sensing and related technologies to problems of regional significance and conduct region specific assessments. The RESACs are addressing problems such as forest growth and health, precision agriculture, land cover and land use mapping and inventory, water resources management, rangeland quality assessment, fire hazard management, integrated watershed and coastal management, assessment of long-term agricultural productivity and sustainability. The outcome of the RESACs will be an enhanced knowledge of potential regional consequences of climate change and variability by regional stakeholders such as state and local governments and private industry. This knowledge will lead to practical advances in the management of regional resources. These advances will be accomplished through regional applications research projects resulting in improved inventories of forest growth, more accurate mapping of land use and land cover, improved assessments of rangeland quality and long-term agricultural productivity, integrated regional management of hydrologic and coastal resources, and reduced risk of loss due to fire resulting in millions of dollars of savings to society.

In addition, ESARP jointly initiated with the United States Department of Agriculture (USDA) thirteen new projects to develop and demonstrate original and improved applications. These projects are in the areas of vegetation mapping and monitoring, risk and damage assessment; and resource management and precision agriculture. Additionally, ESARP and USDA partnered on three pilot projects leveraging the existing successful Land Grant and Space Grant networks into a cooperative NASA ESE-Space Grant/USDA Cooperative Extension Service Strategic Alliance in Geospatial Information Technology (i.e., remote sensing, Geographic Information System (GIS), GPS). Both of these activities will extend ESE's science results and push the existing applications science envelope forward in partnership with USDA. The Alliance will use remote sensing, GIS, GPS and other geospatial technologies to improve the benefits of traditional university extension activities for the Nation's farmers. The outcome will result in the development and validation of at least two new data products for routine decision-making by user organizations in the area of improved knowledge of capability and suitability of agricultural lands and increasingly efficient site specific agricultural techniques. The solicitation for cooperative Applications Research projects with state and local governments will also be completed and released.

In FY 1999, the Type 3 ESIPs (which were selected in late FY1998 as part of the EOSDIS Prototype Federation) focused on applications development and interactions with the potential broader user community. Examples of partner activities include NBC Channel 4 in Washington, D.C. (weather and news) which is developing (system specification completed) an integrated News and Weather Visualization System for use within NBC owned and operated television stations. The system is based on using public and private remotely sensed data that would be used to generate products that can be used on-air. Another example is the New Mexico Earth Data Analysis Center (EDAC) which is working with state, regional, and local problems. To date, they have worked with the New Mexico Land Office and Middle Rio Grande Council of Governments to develop baseline GIS databases and remote sensing applications for land economics and regional hydrology, and have developed a multimedia image sampler to introduce the broader user community to the types of data available for operation and commercial applications. A third partner, Reading Information Technology, Inc. is working to use remotely sensing data as part of a computerized decision support system to assist in determining sea conditions that would decrease shipping cost and determine "optimized" ship routing. To-date, they have established the research partnership with Canadian Steamship Lines (CSL) and have successfully established GIS software on both ship and shore including the vessels' GPS navigation.

As part of its program, ESARP has eleven cooperative projects that involve state and local governments as users in areas such as land use planning, land capability analysis, critical areas management, and water resources management resulting from the solicitation. These projects will result in improved decision support systems in areas of priority needs defined by state and local governments including: land use and land cover inventory; land capability/suitability analysis; critical areas management; water resources management; forest inventory; site and route selection; and emergency preparedness. At least 2 new satellite remote sensing based applications will be developed in these applications areas as a result of these agreements.

Plans

In FY2000, ESARP will initiate additional project activities with state and local governments. One pilot project, the Regional Applications Center for the Northeast (RACNE) will be established to investigate, develop and facilitate use of NASA and other remotely sensed data in Cayuga County, NY and will focus on the management of the 24 county watershed area of the New York Finger Lakes. The RACNE Pilot Project will also provide assistance to other localities in the Northeast, where local use of Geographic Information Technology (GIT) and financial resources appear to be more limited. An additional project will utilize EOSDIS to establish a number of "datamarts" which will be directed at translating the ESE science data products and research results into decision-making information to address state and local everyday problems and needs.

Additionally, ESARP will build on the planning completed in FY1999 with the state and local community in FY1999 and will continue working with the National States Geographic Information Council (NSGIC), Western Governors Association (WGA), Aerospace States Association (ASA), National Association of Counties (NACO), Mid-America States Consortium and National Conference of State Legislatures (NCSL) to plan a set of Applications Research Program demonstrations that will be dedicated to the needs of state and local government resource manages and policy-makers for initiation in FY2001. In FY 2000, ESARP will hold at least five regional workshops for the purpose of increase communication and expanding collaboration with and among the State and Local government user communities. These workshops will begin the process of demonstrating ESE data products and science results to the state and local government community for their use in practical decision-making.

In FY 2000, the ESARP will also continue to demonstrate new applications through the existing ESIP, RESAC, NASA/USDA Cooperative Geospatial Technology Extensions, and Agriculture, Forestry and Range Resources NRA selected projects in areas such as precise agriculture, runoff contaminants from abandoned mines, range land quality assessment, identifying and managing fire hazards, integrated watershed and coastal management, improved impervious surface cover estimates, predictive soil modeling, forest structure determination, crop production/yield determination, and land cover/use mapping and change detection.

In FY2000, the Regional Applications Center (RAC) Program will also be continued through GSFC as a mechanism to extend the benefits of its information technology research to a broader user community. The RAC Program transfers information systems technologies to the outside community by merging NASA's innovations into a functional system provided to regional organizations along with the necessary technical assistance. The RACs serve to support the ESARP's objectives and goal of fostering the self-supporting use of environmental and Earth resource data by regional institutions including state and local governments, universities, consortia and commercial companies. Some examples of existing RACs include the Chesapeake Bay Technical Center of Excellence which is a partnership between 3DI Geographic Technologies, WYE Research Laboratory, University of Maryland-Eastern Shore, Washington College, Chesapeake College and the Talbot County, Maryland Chamber of Commerce directed at the Chesapeake Bay Watershed problems; and the University of Louisiana at Lafayette which supports the oil operations in the Gulf of Mexico and the State of Louisiana's emergency management needs relating to the oil production with remotely sensed data.

ESE will also support Digital Earth activities in FY2000 through funding of on-going Digital Earth technology development tasks, development and implementation of Digital Earth scenarios by the NASA field centers, and the drafting of a formal Digital Earth Program plan. On-going Digital Earth technology development activities include support for the Open GIS Consortium (OGC) - a government and private industry group developing standards and protocols for ready, on-line access to geo-spatial data, the Web Mapping Testbed (WMT) – a prototype system that tests server and client interoperability, and the Digital Earth Reference Model (DERM), a summary of the present state of Digital Earth technology. NASA field centers were solicited for scenarios to demonstrate the Digital Earth concept. Scenarios under development for demonstration by the end of this fiscal year include a Digital Earth "Portal" for museum display, and educational materials involving the interactive use of geo-spatial data. NASA, through code YO, maintains an active role in Digital Earth development through on-going coordination of the Interagency Digital Earth Working Group, (IDEW), and the NASA, through the Digital Earth Office (DEO) at GSFC is developing a formal Digital Earth Program plan that will be submitted for review this year.

COMMERCIAL REMOTE SENSING

The goal of the Commercial Remote Sensing Program (CRSP) is to accelerate the development of a preeminent U.S. remote sensing industry and link ESE scientists with the commercial remote sensing industry to develop mutually beneficial partnerships. To achieve this goal, the CRSP implements partnership programs that demonstrate joint development of technology and applications with private companies, agencies, and educational centers. Examples are the Scientific Data Buy (SDB) and the EOCAP Hyperspectral Initiative.

Accomplishments

In FY 1999, CRSP established over 100 partnerships in stimulating value added remote sensing product development, a 41% increase from 70 in FY 1998. These partnerships were established in areas of education, environmental quality, agriculture, health

and safety, natural hazards, natural resources, and urban infrastructure, and will ultimately generate tangible services and products that benefit society. Examples include maximizing the capacity of waste disposal sites, and providing information to civil defense and insurance companies to lessen the loss of property resulting from natural disasters.

In FY 1999, the USDA and NASA initiated a joint program with four large grower associations; cotton, corn, wheat and soybeans. These grower associations represent over 115,000 U.S. farmers. CRSP is involved in the joint program to facilitate the requirements definitions, translate agricultural requirements to remote sensing technology performance and to provide validation of remote sensing technologies in agricultural industry applications. The intended joint program outcome is a change in agricultural practices that lead to improved efficiencies with less environmental impact from agricultural operations.

The Science Data Purchase is underway processing 83 tasking requests for over 30 sites. These events are the recognition that commercially purchased data can meet the researchers' rigorous requirements for data quality. This activity has led directly to additional mission trade studies for Ocean Winds and POAM III for the ESE Science Division. The overall effect of the program is anticipated to be reduced costs of ESE investigations.

The Workforce Development project in spatial information technology piloted in Mississippi reached fruition and was adopted in August 1999 by Secretary Richard Riley, U.S. Department of Education. This workforce development effort was a featured presentation on the 'Back to School Bus Tour' sponsored by the U.S. Department of Education. In Mississippi the pilot project has resulted in 150 interactive classroom sites through the Mississippi Educational TV Network reaching over 500,000 students.

Plans

In FY 2000, the CRSP will focus EOCAP joint commercial applications research to stimulate the development of new commercial products; e.g., oil spill containment software by EarthSat). These products will ultimately provide the basis for commercial services to continue to support the ongoing geo-spatial needs of the Agricultural and Transportation agencies and the respective markets they represent. Additional commercial sources of science data (from data buy) for global change research and applications will also be investigated for use. The science data will be made available to Earth science researchers for their investigations. These new potential commercial information products will be subject to the necessary verification and validation activities so as to increase customer confidence and product understanding. These products will provide a validated baseline of the new commercial remote sensing satellite and airborne offerings that will be available in the near future.

In FY 2001, efforts will continue to promote the development of new commercial sources of data for science research and applied commercial uses will continue to be pursued. ESE's CRSP and the U.S. Department of Agriculture will jointly conduct at least 30 joint applications research endeavors to increase efficiencies in crop development and crop yield. Working with major associations such as the National Association of Counties, National States Geographic Information Council, National Conference of State Legislators and the National Governors Association a requirements analysis of spatial data needs will be conducted. NASA science and technology have advanced to a state where they can be applied to the operational monitoring of Earth's natural resources. These organizations represent state and local governments where decisions that govern the use and care of Earth resources are made. This initial effort will be to gather geospatial requirements and validate the requirements. The results will lead to a translation to technology performance and validation of state and local government application for geospatial technologies. Also, CRSP will endeavor to increase cost share leveraging with the industry sector, academia and other government

agencies within the EOCAP and ARC programs. The ultimate goal is to effectively stimulate the development of potential commercial data products that will become self-supporting in an emerging commercial remote sensing industry.

EDUCATION

Accomplishments

ESE awarded 50 new graduate fellowships and 17 early career research grants during FY 1999. The fellowships and grants train the next generation of earth scientists and engineers, contributing to a workforce of interdisciplinary scientists to address the study of Earth as a system. These scientists and engineers will use remote sensing knowledge and data in practical fields related to Earth and environmental sciences, and the effects of natural and human-induced changes on the global environment.

In FY 1999, NASA conducted over 300 workshops to train educators in the use of ESE education products. The teachers use Earth system science concepts and applications in lesson plans and classroom activities to educate students about the effects of earth science on the environment. State education systems infuse Earth system science approaches and program content into state curriculum infrastructure. Educators use mission science and applications data to design new Earth system science-related courses to train the next generation of scientists, engineers and educators. These efforts broaden the understanding and sensitivity of students to the processes of the Earth that surrounds them, which they can effect, and are effected by, on a daily basis.

The number of schools participating in GLOBE increase to 7,767, 29% increased from the 5,900 schools participating in 1998, and 84 countries participated, a 20% increase from the 70 countries participating in FY 1998.

Plans

In FY 2000, ESE plans to award at least 50 new graduate student research grants and 20 early career fellowships in Earth science systems. We will continue funding the original EOS interdisciplinary teams through FY 2000 and those selected with the NRAs in FY 1996 through FY 1999. Beginning in FY 2000 we will conduct a NRA for a new group of EOS Interdisciplinary scientists to fit with the new way of doing EOS missions. In FY 2001, we will continue the existing 90 graduate research grants, and award at least 50 new graduate student research grants. During FY 2001, the 17 early career grants will be continued.

During FY 2000, NASA will sponsor at least 350 workshops to train teachers in the use of Earth Science education products. In FY 2001, ESE will sponsor at least 400 Earth science workshops to train educators in the use of ESE education products.

The goals of the GLOBE program will be to increase the number of schools participating in GLOBE to 10,300, a 30% increase over FY 1999, increase the number of participating teachers to 12,000, and increase the number of participating countries in GLOBE from 84, in FY 1999, to 85 in FY 2000. In FY 2001, the volume of teachers participating in the GLOBE program is expected to increase to 13,800 and to increase the number of participating countries to 87.

BASIS OF FY 2001 FUNDING REQUIREMENT

RESEARCH AND TECHNOLOGY

PROPOSED NEW STRUCTURE

TECHNOLOGY INFUSION

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Technology Infusion	[89,000]	[74,515]	89,100
New Millennium Program	[56,100]	[37,100]	50,100
Advanced Information Systems Technology	[6,500]	[12,515]	14,000
Advanced Technology Initiatives	[5,500]	[9,900]	10,000
Instrument Incubator Program	[20,900]	[15,000]	15,000
High Performance Computing and Communications	[14,500]	[21,900]	21,800
Total	[103,500]	[96,415]	110,900

Note: Technology Infusion has been moved from EOS and joined with the effort for HPCC to better account for all technology effort.

PROGRAM GOALS

The Earth Science Technology program develops and demonstrates technologies that will enable future missions, that will reduce the cost of future missions, and that will enable a maximum 3-year acquisition timeline for flight and ground systems. The program consists of five major areas that will lead to the successful and timely development and infusion of technologies into future programs. The New Millennium Program (NMP) validates space platform and instrument technologies required for future missions. NMP space-validated technologies are required before new technologies can be flown on science or operational missions. Advanced Technology Initiatives (ATI) focus and refine ESE technology requirements and advance key component and subsystem technologies required for the next generation of process and monitoring missions. The Instrument Incubator Program (IIP) develops new instruments and measurement techniques at the system level. Such new instruments and measurement techniques will be ready for inclusion in to the ESE 3-year acquisition timeline. Advanced Information Systems (AIS) develops advanced end-to-end mission information system technologies to capitalize on the technological advances of future missions and the increased data of future missions. The goals of the NASA High Performance Computing and Communications (HPCC) project are to accelerate the development, application and transfer of high performance computing technologies to meet the engineering and science needs of the U. S. aeronautics, Earth science, and space science communities and to accelerate the implementation of a national information infrastructure. The ESE HPCC investment will focus on advanced developments of particular interest in Earth and space science.

STRATEGY FOR ACHIEVING GOALS

New Millennium Program

The NMP reflects a commitment to develop new technology to meet the scientific needs of the next few decades and to reduce future EOS costs through focused technology demonstrations for Earth orbiting missions. The Office of Earth Science has joined the Office of Space Science in the NMP in order to capitalize on common work from core technology development projects and specific spacecraft and instrument studies. The program will identify and demonstrate advanced technologies that reduce cost or improve performance of all aspects of missions for the next century, (i.e., spacecraft, instruments and operations). The project objectives are to spawn “leap ahead” technology by applying the best capabilities available from several sources within the government, private industries and universities. These low-cost, tightly controlled developments, the Earth Observers (EOs), will take more risk in order to demonstrate the needed technology breakthroughs and thus reduce the risk of using that technology in future science missions. Missions will be selected based on their ability to meet the science needs of the future by innovative technology that would also decrease the cost and improve the overall performance of space flight missions.

Advanced Information Systems

ESE has initiated the AIS Technology Program. This new program focuses on developing new information systems concepts and capabilities that will enable us to organize, integrate, and capitalize on the increasing data now becoming available.

Advanced Technology Initiative

Increased technology work in the ATI program will be pursued in the areas of sensor and detector systems. Emphasis is being placed on developing new capabilities for Earth science sensors and integrated, autonomous, self-calibrating instruments.

Instrument Incubator Program

The IIP is expected to reduce the cost and development time of future scientific instruments for Earth science. The instrument incubator project will aggressively pursue emerging technologies and proactively close the technology transfer gaps that exist in the instrument development process. The project will take detectors and other instrument components coming from NASA's fundamental technology development projects and other sources, and focus on combining them into new instrument systems which are smaller, less costly, less resource intensive, and which can be developed into flight models more quickly for future Earth science missions. This includes the key follow-on instruments for the EOS.

High Performance Computing and Communications

The NASA HPCC program consists of five discipline-related integrated projects. These projects are Computational Aerosciences (CAS), managed by the Office of Aero-Space Technology; Earth and Space Sciences (ESS), managed by the Office of Earth Science; Remote Exploration and Experimentation (REE), managed by the Office of Space Science; National Research and Education Network (NREN), managed by the Office of Aero-Space Technology, and Learning Technologies (LT).
The implementation of the NASA HPCC program is mainly through coordinated activities at NASA field centers. The ESS project, led by GSFC, will work in close partnership with industry, academia and government. The project used the NASA research announcement process to select ten principal investigator teams and twenty-one NASA/NSF sponsored Grand Challenge investigations and to implement them on advanced parallel computers. The LT project focuses on providing the technology base and applications to accelerate the implementation of the national information infrastructure and to communicate and distribute science and engineering materials to the education community. The LT project uses remote internet technologies developed by NASA and other federally funded agencies to expand the application outreach of its programs to traditionally unserved communities. The Internet is used as the primary means of providing access to and distribution of science and engineering data.

SCHEDULE AND OUTPUTS

Preliminary Design Reviews - Confirms that the proposed project baseline is comprehensive (meets all project level performance requirements), systematic (all subsystem/component allocations are optimally distributed across the system), efficient (all components relate to a parent requirement), and represent acceptable risk.

Earth Observer-1
Plan: February 1997
Actual: February 1997

Earth Observer-2 Plan: June 1998 Actual: October 1998	Revised schedule due to delays in initiating the selection process

Critical Design Reviews - Confirms that the project system, subsystem, and component designs, derived from the preliminary design, is of sufficient detail to allow for orderly hardware and software manufacturing, integration and testing, and represents acceptable risk. Successful completion of the critical design review freezes the design prior to actual development.

Earth Observer-1 Plan: April 1997 Actual: June 1997	Schedule changed to accommodate a grating spectrometer, which was added to the mission

Instruments Delivered - Confirms that the fabrication, integration, certification, and testing of all system hardware and software conforms to their requirements and is ready for recurring operation. Throughout system development, testing procedures or, as appropriate, engineering analysis have been employed at every level of system synthesis in order to assure that the fabricated system components will meet their requirements.

Earth Observer-1 Plan: May 1999 Revised: June 1999	Schedule changed to accommodate the Hyperion alternative for providing the hyperspectral capability following failure to provide wedge filter detectors
Earth Observer-2 Plan: August 2000	After critical design review, it was determined that the SPARCLE system cost had grown significantly. After detailed peer reviews of the technical, cost and schedule status, the project was terminated. However, the progress made on the lidar technology development is still valuable and is being documented

Launch Readiness Dates - Verifies that the system elements constructed for use, and the existing support elements, such as launch site, space vehicle and booster, are ready for launch.

Earth Observer-1 Plan: December 1999 Revised: April 2000	Schedule changed to accommodate the Hyperion alternative for providing the hyperspectral capability and to complete system integration and tests. Currently planned to be launched in April 2000.
Earth Observer-2 Plan: not applicable	Project was terminated due to cost growth.

ACCOMPLISHMENTS AND PROPOSED RESULTS

The Earth Observer (EO-1) Advanced Land Imager (ALI) is the first mission selected under the NMP series and is scheduled for launch in spring, 2000. The EO-1 consists of an ALI instrument, a hyperspectral instrument (called Hyperion), a spacecraft, and numerous advanced technologies as an integral part of the mission. The EO-1 is in Phase C/D and has completed CDR.

Due to the manufacturing difficulties at the ALI detector contractor, the imaging capability of the ALI was rescoped to a grating imaging capability with limited swath coverage to preserve the overall mission schedule and cost. The decision was made in the summer of 1998 to continue the hyperspectral capability, however, through another contractor's design. An additional module called Hyperion to be completed by TRW will provide the hyperspectral functionality. The Hyperion delta CDR was completed this year. In spring, 2000 the EO-1 mission will be launched.

Following selection, development of the Space-Readiness Coherent Lidar Experiment (Sparcle) was started in May 1998 as EO-2. The mission was scheduled to fly an infrared laser in the cargo bay of the Space Shuttle to determine if a space-based sensor can accurately measure global winds within Earth's atmosphere from just above the surface to a height of about 10 miles. The measurement in this region of the atmosphere may lead to improved weather forecasting and a better understanding of climate-related events such as El Niño. The project was terminated due to cost growth. However, the progress in the lidar technology development is still useful for future lidar remote systems.

The Announcement of Opportunity for the EO-3 mission was released in 1999; 4 innovative measurement concepts were selected for concept definition study in February 1999. These concepts would test breakthrough technologies for remote sensing from geostationary Earth orbits. The concept definition studies were completed in September 1999. After detailed review, a Geostationary Imaging Fourier Transform Spectrometer was selected as the EO-3 mission. The concept will test advanced technologies such as large area focal-plane array, new data readout and signal processing electronics, and passive thermal switching, which will be used for measuring temperature, water vapor, wind and chemical composition with high resolution in space and time.

The ATI activities are focusing and refining ESE technology requirements, including system trade studies and the development of technology roadmaps. Architectural concepts developed under the advanced concepts element are carried forward to determine the specific system, subsystem and component performance metrics required for their implementation. A NASA Research Announcement (NRA) for instrument-related technologies was released in 1999 and proposals are currently in the evaluation phase. Awards are expected in the first quarter of 2000.

This element also advances key component and subsystem technologies required for the next generation of process and monitoring missions. An example is the current sensors and detectors project that includes the development of Light-Detection and Ranging (LIDAR) technologies for profiling winds and chemical constituents within the Earth's atmosphere, spectrometers that can return high quality EOS level-2 science products at lower total mission cost and radiometers for passive microwave and millimeter wave remote sensing. These activities are complementary to the Space Science Enterprise-supported Cross-Enterprise Technology Development Program (CETDP), NASA's primary advanced technology program developing component and subsystem technologies at early stages of maturity. While CETDP has the charter for generic technologies with value to multiple NASA enterprises, ESE's advanced technology initiatives element is focused on technologies specific to ESE needs.

For 1999 the ATI element includes the development of LIDAR technologies for profiling winds and chemical constituents within the Earth's atmosphere, spectrometers that can return high quality EOS level-2 science products at lower total mission cost and radiometers for passive microwave and millimeter wave remote sensing.

Also under this element, systems trade studies were completed in 1999 in the following areas:

- Visible/Near-IR Remote Sensing Options
- High Data-Rate Instrument Requirements
- Systems Issues on Formation and Constellation Flying
- LIDAR Studies
- Molniya Earth Orbit (MEO) Applications-Science/Cost Benefits
- Geostationary Orbit (GEO) Missions
- Advanced Microwave Radiometry
- Global Positioning System (GPS) Surface Reflection Technology for Space
- Tropospheric Measurement Options

The last quarter of 1999 saw the initiation of the Earth Science AIS Technology Program. An NRA was released with five areas of interest emphasized: 1) On-board Satellite Data Processing and Intelligent Sensor Control; 2) On-board Satellite Data Organization, Analysis, and Storage; 3) Data Transmission and Network Configuration; 4) Intelligent Platform Control; and 5) Information Systems Architectures and Standards. Awards are expected in early 2000.

The IIP supports the development of new instruments and measurement techniques from paper studies through laboratory development and ground or air validation. NRAs are used as the vehicle to search the combined public and private science/technology community for the best new ideas and development capability. NASA received 123 proposals of which 27 have been selected and are under contract. Selected projects include three from industry, six from NASA field centers, eight from universities and ten from national laboratories.

The advanced geostationary study effort has been evaluating various new imaging, sounding, and lightning mapper instrument concept designs and technologies that could be applied to using geosynchronous orbit as a cost effective vantage point for supporting Earth science research objectives as well as NOAA observational requirements. The study effort has also investigated technologies and concepts for advance geosynchronous spacecraft and associated ground data processing and distribution techniques required to support the advanced instrumentation. All activities have been closely coordinated between NASA and NOAA.

In FY 2000 and 2001 the technology program will continue to achieve success in timely development and infusion technologies, thereby enabling future missions and reducing their total cost. Indicators of this performance will be to; annually advance at least 25% of funded instrument technology developments one Technology Readiness Level (TRL); develop advanced information systems technologies, concepts for processing, archival, access, and visualization of ESE data; develop at least 3 technologies to demonstrate in space with the third Earth Observer New Millennium satellite; transfer at least one technology development to a commercial entity or infuse into a flight mission for operational use. These performance indicators will be refined as the Enterprise gains experience with its technology development initiatives.

BASIS OF FY 2000 FUNDING REQUIREMENT

OLD STRUCTURE

CONSTRUCTION OF FACILITIES

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Construction of Facilities	1,500	1,000

For additional detail, refer to the Mission Support, Construction of Facility section.

BASIS OF FY 2000 FUNDING REQUIREMENT

RESEARCH AND TECHNOLOGY

PROPOSED NEW STRUCTURE

CONSTRUCTION OF FACILITIES

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Construction of Facilities	[1,500]	[1,000]	--

For additional detail, refer to the Mission Support, Construction of Facility section.

BASIS OF FY 2001 FUNDING REQUIREMENT

OPERATIONS

OLD STRUCTURE

OPERATIONS, DATA RETRIEVAL AND STORAGE

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Mission operations	55,500	47,600
(Upper Atmosphere Research Satellite)	8,200	6,700
(Total Ozone Mapping Spectrometer)	2,700	3,200
(Ocean Topography Experiment (TOPEX)	11,000	9,700
(Tropical Rainfall Measuring Mission)	10,900	11,000
(Satellite Laser Ranging)	5,900	--
(Earth Science)	16,800	17,000
HPCC	14,500	21,900
INFO SYSTEMS	6,100	7,600
Total	76,100	77,100

BASIS OF FY 2001 FUNDING REQUIREMENT

OPERATIONS

PROPOSED NEW STRUCTURE

MISSION OPERATIONS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Mission operations			
(Upper Atmosphere Research Satellite)	[8,200]	[6,700]	6,700
(Total Ozone Mapping Spectrometer)	[2,700]	[3,200]	4,400
(Ocean Topography Experiment (TOPEX)	[11,000]	[9,700]	6,000
(Tropical Rainfall Measuring Mission)	[10,900]	[11,000]	9,700
(Satellite Laser Ranging)	[5,900]	--	--
(Earth Science)	[16,800]	[17,000]	15,900
Total	[55,500]	[47,600]	42,700

Note: In the proposed new structure, HPCC is located under Applications, Commercialization and Education, and Information Systems is under Earth Science Program Science

PROGRAM GOALS

Operations, Data Retrieval and Storage (ODRS) provides the data and data products from EOS precursor missions, including the UARS, TOPEX, TOMS, NSCAT and TRMM, required to understand the total Earth system and the effects of humans on the global environment.

STRATEGY FOR ACHIEVING GOALS

This project supports the observations and data management portion of Earth science activities. The project will achieve its goals through the following: mission operations, high performance computing and communications, and information systems. The data and data products from this project have or will migrate to the EOSDIS.

Mission Operations

The objectives of the mission operations program are to acquire, process, and archive long-term data sets and validated data products. These data sets support global climate change research in atmospheric ozone and trace chemical species, the Earth's radiation budget, aerosols, sea ice, land surface properties, and ocean circulation and biology. Funding provides for operating spacecraft such as UARS, TOPEX, ERBS, TOMS, TRMM, and processing of acquired data. Key users of UARS data include NOAA, the Naval Research Laboratory, GSFC, JPL, Canada, the United Kingdom, and a number of universities including the University of Michigan, the Georgia Institute of Technology, the University of Washington, the State University of New York, and the University of Colorado. Key TOMS proponents include NOAA, Russia (manifested a TOMS on their Meteor 3 satellite launched in 1991), Japan (manifested a TOMS on their ADEOS satellite launched in 1996). Key ERBS users are a diverse set of institutions including NOAA (manifested Earth Radiation Budget Experiment (ERBE) sensors on NOAA-9 and -10 launched in the 1980's), GSFC, LaRC, the State University of New York, Oregon State University, and the Scripps Institution of Oceanography.

Key participants involved in the Alaska Synthetic Aperture RADAR (SAR) Facility include the European Space Agency Remote Sensing Satellite (ERS)-1 and -2), Japan Earth Remote Sensing Satellite (JERS)-1), Canada (RADARSAT), GSFC, JPL, and the University of Alaska which hosts the ASF. Participants in the analysis of SIR-C/X-SAR data, in addition to JPL, represent nations on almost every continent and include: Italy, Saudi Arabia, China, Australia, France, Canada, Brazil, the United Kingdom, and Germany.

The Satellite Laser Ranging (SLR) System is NASA's contribution to a worldwide laser ranging network. In additional to providing extremely precise tracking for a number of spacecraft (including TOPEX and a host of international missions), the SLR network makes significant contributions to Earth science (such as precise measurements of the gravity field and the station's vertical position with respect to the Earth's center of mass).

The Optical Transient Detector (OTD) instrument has numerous customers for data including NASA, NOAA, USAF, Massachusetts Institute of Technology, Texas A&M, University of California at Los Angeles, Colorado State, and international requests for data from Chile; German Aerospace Center (DLR); University of Frankfurt, Germany; the Swiss Institute of Atmospheric Physics; South Africa; Mexico; Hungary; Tel Aviv University and Haifa University, Israel; the United Kingdom Meteorological Office; France; Potsdam Institute for Climate Impact Research, Germany; and China.

SCHEDULE AND OUTPUTS

OPERATIONAL SPACECRAFT/INSTRUMENTS

Common to all missions:	
Archive 95% of planned data acquisition	The primary criteria for success of an operational spacecraft are to obtain 95% of the planned data acquisition.
UARS (launched September 1991) continuing operations	The spacecraft launched in September 1991 with an expected five-year mission life. It has gone well beyond the expected mission life providing data to support improvements monitoring the processes that control upper atmospheric structure and variability, the response of the upper atmosphere to natural and human-induced changes, and the role of the upper atmosphere in climate variability. The spacecraft is transitioning to real-time operations due to a second recorder failure in November 1999. 95% operational. Processing 4,000 Bytes/second.
TOPEX/Poseidon (launched August 1992) continuing operations	The spacecraft launched in August 1992 with an expected three-year mission life. The extended mission was defined to be three additional years. It is now in the final year of this extended mission life. 100% operational. Processing 2000 Bytes/second.
ERBS/ERBE/SAGE II (launched Oct. 1984, December 1984 and September 1986) continuing operations	The ERBS spacecraft launched in October 1984. It has gone well beyond the expected mission life. 67% operational. SAGE processing 1,600 Bytes/second. ERBE processing 200 Bytes/second.
Alaska SAR Facility Missions: ERS-1 (launched 1991) JERS-1 (launched 1992) ERS-2 (launched 1995) RADARSAT (launched 1995) ADEOS (launched 1996)	The Alaska SAR Facility is a ground receiving station and data processing station with no "end of life" defined. It supports ERS-1, JERS-1, ERS-2, and RADARSAT. All of these are international missions. There are currently no unique metrics defined for ASF other than the common metric listed above. 67% operational. Processing 575 Bytes/second.

OTD (launched 1995) continuing operations	This instrument was launched in 1995 as a six-month technology demonstration. It has far exceeded its designed mission life.
TOMS FM-3 (launched July 1996) continuing operations	The TOMS-EP spacecraft was launched in July 1996 with an expected five-year mission life. It is currently in its primary mission phase. The first global ozone image was produced and released September 13, 1996. Automated processing and distribution of science products began September 20, 1996 and Internet distribution started on October 7, 1996. 100% operational. Processing 250 Bytes/second.
TRMM (Launched November 1997) continuing operations	The spacecraft launched in November 1997 with a three-year mission life. All operations are nominal, except the CERES instrument is non-operational due to an anomaly with Data Acquisition Assembly Converter. 100% operational. Processing 250,000 Bytes/second.
SeaStar / SeaWifs / Ocean Color (Launched August 1997 continuing operations for data processing)	The spacecraft launched in August 1997. This is a data buy from Orbital and the operation of the spacecraft is an Orbital responsibility. 100% operational. Processing 41,700 Bytes/second.
Landsat-7 **Launched April 1999**	Landsat-7 was launched April 15, 1999 and declared operational in July 1999. After NOAA withdrew from the program in late 1998, the USGS agreed to operate the satellite through FY 2000. 100% operational. Processing 250 scenes/day.

ACCOMPLISHMENTS AND PROPOSED RESULTS

Data has been acquired, processed, disseminated, and archived to meet mission requirements for user availability of timely and accurate data products for global and/or regional monitoring purposes from all operational spacecraft and instruments. The current emphasis on global modeling in support of policy decisions on such matters as the impact of deforestation, ozone depletion, and environmental quality worldwide has led to the acquisition and manipulation of unprecedented amounts of environmental data. The accompanying computational demand has led to a doubling of production computing capacity and quadrupling of mass storage capacity in the last two fiscal years. These added demands are being addressed in the agency's initiative to consolidate supercomputer-based information systems.

In the mission operations project, responsibility for assigned missions is assumed 30 days after launch. Data are acquired, processed, disseminated, and archived to meet mission requirements for user availability of timely and accurate data products.

User requirements will be met in 2000 and 2001 by continuing operations of on-orbit spacecraft and instruments including the UARS, TOPEX, and ERBS missions; and continuing receipt of ERS-1, JERS-1, and RADARSAT data at the Alaska SAR Facility, in addition to , OTD, SeaStar/SeaWifs, TOMS and TRMM.

BASIS OF FY 2001 FUNDING REQUIREMENT

PROPOSED NEW STRUCTURE

INVESTMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Minority University Research & Education Program (MUREP)	[7,300]*	[7,300]*	8,800
Education	--	--	1,500
Total	[7,300]*	[7,300]*	10,300

* FY 1999 and FY 2000 MUREP covered in Applications, Commercialization and Education (ACE).

PROGRAM GOALS

The above funding requirements represent the ESE budget contribution to the Minority University Research and Education Programs (MUREP) and the Education Program.

STRATEGY FOR ACHIEVING GOALS

The Earth Science Strategic Enterprise investments in higher education institutions include Federally mandated outreach to the Nation's Historically Black Colleges and Universities (HBCUs) and Other Minority Universities (OMUs), including Hispanic-Serving Institution and Tribal Colleges and Universities. This outreach is achieved through a comprehensive and complementary array of strategies developed in collaboration with the Office of Equal Opportunity Programs. These strategies are designed to create a broad-based, competitive aerospace research capability within Minority Institutions (MI's). This capability fosters new aerospace science and technology concepts by integrating Earth Science Enterprise-related cutting-edge science and technology concepts, practices, and teaching strategies into MI's academic, scientific and technology infrastructure. As result, increasing the production of more competitive trained U.S. students, underrepresented in NASA-related fields who, because of their research training and exposure to cutting-edge technologies, are better prepared to enter graduate programs or the workplace. Other initiatives are focused on enhancing diversity in the Earth Science Strategic Enterprise's programs and activities. This includes exposing faculty and students from HBCUs and OMUs, and students from under-served schools, with significant enrollments of minority students, to the Enterprise's research efforts and outcomes, educational programs, and activities. To support the accomplishment of the Enterprise's mission, these programs are implemented through NASA Centers and JPL. The Centers and JPL support the MUREP through use of their unique facilities, program management and grant administration, and commitment of their personnel to provide technical assistance and assist in other facets of program implementation. Extensive detail as to how this funding is utilized is located under the MUREP portion of the budget.

In carrying out its Education Program, NASA is particularly cognizant of the powerful attraction the Earth Science mission holds for students and educators. The unique character of Earth Science exploration, scientific, and technical activities has the ability to captivate the imagination and excitement of students, teachers, and faculty, and channel this into an investment which support NASA's Education Program.

In fulfilling its role to support excellence in education as set forth in the NASA Strategic Plan, the NASA Education Program brings students and educators into its missions and its research as participants and partners. NASA provides the opportunity for educators and students to experience first hand involvement with Earth Science Enterprise scientists and engineers, facilities, and research and development activities. Examples of such opportunities include the Learning Technologies Program, a new Undergraduate Internship Program, and the Graduate Student Researchers Program. The participants benefit from the opportunity to become involved in research and development endeavors, gain an understanding of the breadth of Earth Science activities, and return to the classroom with enhanced knowledge and skills to share with the entire education community. Detail as to how this funding is utilized is located under the NASA Education portion of the budget.

BASIS OF FY 2000 FUNDING REQUIREMENT

OLD STRUCTURE

GLOBAL OBSERVATIONS TO BENEFIT THE ENVIRONMENT (GLOBE)

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Global Observations to Benefit the Environment	5,000	5,000

For additional detail, refer to the Applications, Commercialization, and Education section.

BASIS OF FY 2000 FUNDING REQUIREMENT

OLD STRUCTURE

LAUNCH SERVICES

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Launch Services.....		4,200

For additional detail, refer to EOS, Terra section.

BASIS OF FY 2000 FUNDING REQUIREMENT

OLD STRUCTURE

SHUTTLE RADAR TOPOGRAPHY MISSION

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Shuttle Radar Topography Mission.....		6,200

For additional detail, refer to the Earth Probes section.